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Biases in Children's Cognitive Styles: Investigating Local, Global, and Rule-Based Processing in Autism Spectrum Disorders and Typical Development

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LOYOLA UNIVERSITY CHICAGO

BIASES IN CHILDREN'S COGNITIVE STYLES:
INVESTIGATING LOCAL, GLOBAL, AND RULE-BASED
PROCESSING IN AUTISM SPECTRUM DISORDERS
AND TYPICAL DEVELOPMENT

A DISSERTATION SUBMITTED TO
THE FACULTY OF THE GRADUATE SCHOOL
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

PROGRAM IN DEVELOPMENTAL PSYCHOLOGY

BY

SANDRA B. VANEGAS

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ABSTRACT

Autism Spectrum Disorders (ASD) is classified as a pervasive developmental disorder that presents a triad of impairments across communication, social behavior, and restricted interests (American Psychiatric Association, 2000). To date, many attempts have been made to explain the cognitive profiles of children and adults with ASD. Three prominent theories, Weak Central Coherence (Frith, 1989), Systemizing (Baron-Cohen, 2002), and Executive Dysfunction Theory (Pennington & Ozonoff, 1996), may together provide a plausible explanation for the cognitive biases of individuals with ASD.

Weak Central Coherence (WCC) Theory proposes that individuals with ASD have difficulty learning new information due to a fixation towards local or detailed information at the exclusion of meaning, such as the gist (Happé & Frith, 2006). According to Systemizing Theory, individuals with ASD learn new information by detecting and following set rules (Baron-Cohen, 2002). Both theories fail to consistently account for the cognitive profiles of children with ASD. As an alternative, the Executive Dysfunction Theory has been proposed to account for the cognitive and behavioral profiles in ASD (e.g., Rajendran & Mitchell, 2007). The current study aims to evaluate these cognitive theories within the same children to determine how they each may contribute to the cognitive profile of ASD.

The present study finds that the cognitive biases for rule-based information influences language abilities in distinct ways within ASD children. Additionally,

children with High-Functioning Autism rely on rule-based knowledge, whereas children with Asperger's Syndrome and typically developing children rely on contextual information when presented with counterfactual statements. Finally, executive functioning appears to play a bigger role in cognitive biases for children with Asperger's Syndrome than High-Functioning Autism and Typically Developing children. These differences provide a foundation for understanding how children with ASD may learn information more efficiently. The current study aims to combine measures of central coherence, systemizing, and executive functioning to understand whether children with autism possess greater biases towards local-, global-, or rule-based cognitive processing biases.

CHAPTER ONE

INTRODUCTION

Autism Spectrum Disorders (ASD) are classified as pervasive developmental disorders that present a triad of impairments across communication, social behavior, and restricted interests (American Psychiatric Association, 2000). ASD diagnoses have been on the rise since initial reports were made by Kanner (1943), with the current prevalence rate of 1 in 88 children (Center for Disease Control, 2012) and as low as 1 in 55 school-aged children (Blumberg et al., 2013). As more children are diagnosed with ASD, continued investigation into the underlying mechanisms is vital. More recently, the cognitive profile of ASD has been investigated for viable clues to improve current intervention and educational strategies for these children.

To date, many attempts have been made to explain the cognitive profiles of children and adults with ASD. Most theories can explain specific behaviors (e.g., socially inappropriate interactions, and repetitive or “stimming” behaviors), although few can fully account for the diverse repertoire of behaviors. Recent reviews have suggested that future studies are needed to integrate various disciplines of research to better understand the relationships between ASD symptoms rather than view ASD symptoms in isolation (Happé & Ronald, 2008; Leekam & McGregor, 2008; Rajendran & Mitchell, 2007; Volkmar, Chawarska, & Klin, 2005).

Three prominent theories, Weak Central Coherence (Frith, 1989), Systemizing (Baron-Cohen, 2002), and Executive Dysfunction Theory (Pennington & Ozonoff, 1996), may together provide a plausible explanation for the cognitive biases of individuals with ASD. Weak Central Coherence (WCC) Theory proposes that individuals with ASD have difficulty learning new information due to a fixation towards detailed information at the exclusion of meaningful information, such as the gist (e.g., Frith, 1989; Happé & Frith, 2006). According to Systemizing Theory, individuals with ASD learn new information by seeking predictable relationships and following set rules (Baron-Cohen, 2002). Evidence for Weak Central Coherence and Systemizing Theories currently requires further speculation as both fail to consistently account for the cognitive profiles of children with ASD.

As an alternative to these theories, the Executive Dysfunction Theory has been proposed to account for the cognitive and behavioral profiles in ASD (e.g., Ozonoff, Pennington, & Rogers, 1991; Rajendran & Mitchell, 2007). This cognitive theory of ASD originally surfaced upon observation of the parallels in impaired performance across executive function tasks between individuals with ASD and individuals with specific brain injuries (Damasio & Maurer, 1978). The executive function performance was similar across both groups in terms type and degree of deficit, and have been attributed to the integrity of frontal lobe function (e.g., Hughes, Russell, & Robbins, 1994; Johnson et al., 2007; Ozonoff et al., 1991). Individuals with ASD have also demonstrated difficulties across areas of executive functioning, such as auditory working memory (e.g., Kenworthy et al., 2005), inhibition (e.g., Geurts, Verté, Oosterlaan,

Roeyers, & Sergeant, 2004; Hill, 2004; Kenworthy et al., 2005; Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006), planning (e.g., Geurts, et al., 2004), and cognitive flexibility (e.g., Christ, Kanne, & Reiersen, 2010; Geurts, et al., 2004; Hughes, et al., 1994; Kenworthy et al., 2005; Ozonoff, 1997; Verté, et al., 2006). These executive function abilities may hold the missing link between the inconsistencies of WCC and Systemizing Theories. Although the WCC and Systemizing Theories can account for some behaviors in ASD, other behaviors may be linked to executive functioning. Therefore, it is important to evaluate the present theories, WCC and Systemizing Theory while taking into account the role of executive functioning.

This multi-faceted theoretical approach may be more suitable in understanding the cognitive biases of ASD, considering the importance of experience in the acquisition and development of cognitive skills (Happé & Booth, 2008). Hence, early biases may limit the experiences children with ASD encounter and this in turn may shift their developmental trajectories in ways that magnify differences when compared to typically developing children (Burack, Iarocci, Flanagan, & Bowler, 2004). The current study aims to combine measures of central coherence, systemizing, and executive functioning to understand whether children with ASD possess greater biases towards local, global, or rule-based information.

Literature Review

Autism was first diagnosed in 1943 upon observation that many children displayed behavioral patterns that distinguished them from children with other clinical diagnoses (Kanner, 1943). More strikingly was the desire for aloneness that was evident

among these children, coupled with rigid, repetitive behaviors and limited communication. Although progress has been made in the past seven decades towards understanding ASD, much is yet to be discovered about the causes, treatments, and outcomes of ASD. The defining characteristics of ASD are based on three principal areas that affect the individual's daily functioning: Impairments in social interactions, communication, and the presence of restricted and repetitive behaviors and interests, coupled with a delay in behaviors and abilities typically acquired by the age of 3 (APA, 2000).

Cognitive functioning in ASD may be quite varied, and parallels the heterogeneity evident across other domains in ASD. Reviews of joint attention have found that children with ASD differ from typically developing children in the quantity and quality of communicative acts, such as eye contact, pointing and requesting (e.g., Bruinsma, Koegel, & Koegel, 2004). The inattention to social cues has been associated with difficulties in acquiring Theory of Mind (ToM; Baron-Cohen, Leslie, & Frith, 1985; Tager-Flusberg, 2007). Theory of Mind is the understanding that another person's thoughts and beliefs (i.e., mental states) can differ from one's own (Wimmer & Perner, 1983). Performance on standard false belief tasks show that children with ASD are often delayed if not impaired, in their understanding of others' mental states (e.g., Baron-Cohen et al., 1985; Colle, Baron-Cohen, & Hill, 2007; Frith & Happé, 1999; Tager-Flusberg, 2007; Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998).

ToM has also been implicated as contributing to deficits in language abilities in ASD (Happé, 1995). The lack of social awareness has been cited as a source for the

deviance in learning language in ASD. Whereas typically developing children use their social interactions as a primary source of linguistic knowledge, children with ASD typically do not engage in social interactions in a functional manner (e.g., Groen, Zwiers, van der Gaag, & Buitelaar, 2008; Rice, Warren, & Betz, 2005). Although children with ASD may verbalize words or phrases, this is usually manifested as echolalia in low functioning children (i.e., repeating phrases as heard; Kanner, 1943; McEvoy, Loveland, & Landry, 1988; Schuler, 2003) or as specific deficits in syntax/phonology or semantics/pragmatics (e.g., Groen et al., 2008; Kjelgaard & Tager-Flusberg, 2001; Rapin, Dunn, Allen, Stevens, & Fein, 2009). Due to the distinct cognitive profiles of ASD, it is vital to understand the mechanisms that guide the acquisition and processing of new information in children with ASD.

Over the past seven decades, many theories have surfaced in attempts to understand the underlying processes of ASD. Initially, theories focused on modular accounts identifying and explaining specific symptoms within the diagnostic triad, such as social impairments or repetitive behaviors (e.g., Leslie, Friedman, & German, 2004; Surian, Baron-Cohen, & Van der Lely, 1996). More recently, domain-general accounts have emerged, evaluating the triad of symptoms within a continuum of typical and atypical behaviors (e.g., Happé & Frith, 2006; Minshew & Goldstein, 1998). Weak Central Coherence (WCC) Theory and Systemizing Theory are two current domain-general accounts that, together, may aid in understanding children's cognitive biases.

Weak Central Coherence Theory

Central coherence is the natural tendency for individuals to seek and derive meaning from their surroundings (Frith, 1989). Preference for global or meaning-based information is evident across the lifespan and across multiple domains. Infants as young as three months of age exhibit preferential looking and require less familiarization for global visual stimuli than for local properties of stimuli (e.g., Colombo, Freeseaman, Coldren, & Frick, 1995; Frick, Colombo, & Allen, 2000). An early focus on the gist or global aspects of information serves to condense vast amounts of information to a manageable set that can be processed efficiently (Brainerd & Reyna, 1990). Later in life, gist and global processing abilities have been utilized to detect intact cognitive functioning in adolescents and seniors (e.g., Chapman, Anand, & Sparks, 2006; Gamino, Chapman, & Cook, 2009). Based on this evidence across the lifespan, central coherence can be viewed as a valid indicator of typical cognitive functioning. An absence of drive towards meaning can be considered a marker for atypical cognitive functioning.

Central coherence in typical development. To date, only one study has thoroughly evaluated central coherence in typical development (Pellicano, Maybery, & Durkin, 2005). Four- and five- year olds were assessed on central coherence (CC), executive function (EF), and Theory of Mind (ToM) skills. The aim of this study was to determine whether these skills were driven by similar cognitive processes.

ToM was measured with standard false-belief tasks where a character stores an object and in their absence, the object is moved to another location. The child is then required to predict the character's behavior in their search for the object. The EF tasks

tapped cognitive skills such as higher-order planning, cognitive flexibility, and working memory. CC measures assessed children's visuospatial skills in processing distinct aspects of materials, such as locating an image hidden in a meaningful or ambiguous picture, constructing three-dimensional models based on two-dimensional images, and copying increasingly difficult images consisting of multiple components.

Pellicano et al. found that older children (5-year-olds) responded faster and more accurately on the CC tasks than younger children (4-year-olds). Furthermore, two common cognitive processes were found to underlie the CC measures: Visuospatial Construction and Speed/Persistence in task performance. Further exploration of CC in typical development investigated potential relationships between CC, ToM and EF tasks. These analyses found that only visuospatial construction was positively correlated to Composite ToM tasks, even after controlling for age; however, this relationship disappeared once verbal and nonverbal abilities were accounted for. Visuospatial construction was also found to be positively associated with the EF tasks, even after accounting for age, verbal and nonverbal abilities. This finding indicates that children's planning abilities and working memory could play a significant role in children's abilities to disembed and integrate visual information in typical development.

However, a limitation of this study lies in the exclusive use of visuospatial tasks to measure CC. It is uncertain whether visuospatial construction truly represents CC or whether it is merely representing a visual-spatial processing ability. Furthermore, the relationship between CC and ToM is also unclear as the association disappeared once verbal and nonverbal abilities were accounted for. The relationship between CC and EF

illustrates that children's visuospatial construction may be tied to other cognitive abilities (e.g., planning and working memory). Children's ability to integrate visuospatial information may be dependent on children's ability to plan and encode the information. This finding merits further evaluation in determining if CC and EF measures display similar associations in children with ASD.

Weak central coherence in Autism Spectrum Disorders. The WCC theory of ASD first proposed by Frith (1989) rests on two basic principles: 1) individuals with ASD possess a natural bias to focus on the local properties of information and 2) individuals with ASD exhibit difficulties integrating the local properties of information into meaningful representations. This style of processing information is in direct contrast to that found in typical development (e.g., Mondloch, Geldart, Maurer, & de Schonen, 2003), and may explain specific behaviors and interests of individuals with ASD. To date, there is variable support for these principles that may be attributed to the unbalanced comparisons between visuospatial and linguistic tasks and inconsistent task demands across studies (e.g., Happé & Booth, 2008; López, 2008; López & Leekam, 2003; Loth, Gomez, & Happé, 2008; Mottron, Burack, Iarocci, Belleville, & Enns, 2003). The visuospatial and linguistic domains are two predominant areas studied in relation to WCC theory, thus only the relevant literature within these domains will be presented.

Visuospatial assessment of WCC. The visuospatial domain is a prime area for study in ASD, as these studies often do not require verbal responses or linguistic processing, an area of known difficulty in ASD. The stimuli used in visuospatial tasks

are appealing to young children and can be modified to fit specific research questions with relative ease.

In early studies of children with ASD, researchers noted discrepancies in children's performance across subtests within standardized measures. For example, although children with ASD performed poorly on verbal measures of the Wechsler scales, they exhibited superior performance on nonverbal measures, specifically, the Block Design subtest (Frith, 1989). The Block Design subtest from the Wechsler Scales presents the child with a two-dimensional image comprised of black and white segments and the child is asked to replicate the two-dimensional image using nine blocks (Wechsler, 1989). Children's scores are based on the amount of time required to complete the task, as well as the accuracy in duplicating the two-dimensional image.

The WCC theory accounts for the performance of children with ASD in that they are able to mentally partition the two-dimensional image into its constituent parts, whereas typically developing children have difficulty overcoming the global image when completing the task. When the two-dimensional image is segmented to correspond with the blocks, typically developing children perform comparably to children with ASD (e.g., Best, Moffat, Power, Owens & Johnstone, 2008; Shah & Frith, 1993). By adding the segmentation to the two-dimensional image, it seems that typically developing children are afforded the same opportunity to complete the task. This suggests that children with ASD may be segmenting the design in their mental representations and are not hindered by the global construct when reproducing the two-dimensional image.

Similarly, in the Children's Embedded Figures Test (CEFT; Witkin, Oltman, Raskin, & Karp, 1971), children are required to locate a figure or shape embedded within a larger, meaningful picture. Successful performance on this task requires the ability to disengage from the larger, meaningful picture and analyze its constituent parts. Across multiple studies, children as young as three years diagnosed with autism and pervasive developmental disorder (PDD) completed this task faster than typically developing children. This occurred even when typically developing children were matched for chronological age, and verbal and nonverbal IQ to children with autism and PDD (e.g., Jarrold, Gilchrist, & Bender, 2005; Keehn et al., 2009; Morgan, Maybery, & Durkin, 2003; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005; Pellicano, Maybery, Durkin, & Maley, 2006).

Longitudinal analysis of visuospatial CC tasks in ASD has found that CC is stable in early childhood (i.e., 4- to 10-years; Pellicano, 2010a). Other studies have also found that parent-reported repetitive and restricted behaviors in children with autism are predictive of superior performance and faster response times on the CEFT (e.g., Chen, Rodgers, & McConachie, 2009; Evans, Elliott, & Packard, 2001). This finding indicates that children's repetitive behaviors associated with the triad of impairments in autism, corresponded with a cognitive bias favoring local features over the global picture. This evidence supports the theory that children with ASD are able to ignore the meaningful information and process the image as a construct of individual elements.

Based on this behavioral evidence, children with ASD process local aspects of stimuli (i.e., embedded figures within larger pictures), with more ease than typically

developing children. A recent fMRI study has also illustrated that differences between children with autism and typically developing children (between 7 and 12 years of age) on the CEFT may result from distinct neural processing that occurs during this task (Lee et al., 2007). CEFT performance differences were salient as typically developing controls elicited greater frontal recruitment and bilateral activation in temporal, parietal, and occipital regions, whereas children with autism only elicited dorsal premotor regions and unilateral activation of the parietal and occipital regions. This finding supports the principles of WCC theory that children with ASD process detailed information more readily, requiring less cognitive resources when compared to typically developing children.

This evidence indicates that individuals with ASD possess a natural bias to observe the local properties of objects, whereas typically developing children are naturally biased by the gestalt of objects. Studies of adults have also found strong relations between reaction times on the Embedded Figures Test (EFT) and autism traits as measured by the *Autism Spectrum Quotient – Adult Version* (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). In these studies, individuals who reported a greater number of autism traits completed the EFT faster than individuals who reported a fewer number of autism traits (e.g., Almeida, Dickinson, Maybery, Badcock, & Badcock, 2010; Grinter, et al, 2009).

The relationship between overall autism traits and CEFT performance has yet to be evaluated in children. If this association is found in children with ASD, many plausible relationships could be deducted. For example, underlying neural structures in

children with ASD could be biasing their focus towards local features of stimuli.

Another explanation would posit the cognitive bias towards local properties as the driving force behind autism traits. The current study will capture both reports of autism traits and CEFT reaction times to determine if the relationship found in adults translates to children.

Another task used to assess WCC is the Navon task (Navon, 1977) that presents hierarchical information to assess local and global processing in typical and atypical populations across the lifespan (e.g., Barrett, Crucian, Schwartz, Nallamshetty, & Heilman, 2001; Cassia, Simion, Milani, & Umiltà, 2002; Förster, Liberman, & Shapira, 2009; Haimov, Hadad, & Shurkin, 2007; Mondloch, et al., 2003; Poirel, Mellet, Houdé, & Pineau, 2008; White, O'Reilly, & Frith, 2009). Hierarchical figures, typically in letter-form, are composed of congruent or incongruent local features. For example, a congruent figure consists of a large "X" (global form) comprised of many small "x's" (local feature). An incongruent figure might consist of a large "X" (global form) comprised of many small "s's" (local feature). The main objective of the Navon task is to evaluate the interference between the local features (e.g., "s") and the global form (e.g., "X") on incongruent trials.

Performance on the Navon task in children with ASD varies, some studies find no difference between children with ASD and typically developing control groups (e.g., Deruelle, Rondan, Gepner & Fagot, 2006; Mottron, et al., 2003; Ozonoff, Strayer, McMahon & Filloux, 1994; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000); however, other studies have found differences only under certain conditions or specific participant characteristics, such as priming selective attention or increased head or brain

size (e.g., Plaisted, Swettenham & Rees, 1999; Rinehart, Bradshaw, Moss, Brereton & Tonge, 2001; White et al., 2009). The inconsistent findings of the Navon task make it difficult to understand whether children with ASD present a processing bias in favor of local information over global information, as the current evidence does not converge consistently with results from the Block Design subtest and the CEFT.

The current research hopes to illuminate the potential strategies children with ASD use when processing local and global information such as the embedded figures of the Children's Embedded Figures Test. Although the evidence for visuospatial WCC is variable, linguistic measures may provide a more thorough view of local and global processing in children with ASD.

Linguistic assessment of WCC. Children with ASD often exhibit difficulties in acquiring language, and when acquire language, often exhibit difficulties in production and comprehension (e.g., Boucher, 2003; Groen et al., 2008; Jarrold, Boucher, & Russell, 1997; Pickles et al., 2009; Tager-Flusberg, 2001, 2003). Despite these language difficulties, simple tasks can assess local and global biases in children with ASD as predicted by WCC theory. The Homograph Task was devised to assess whether children with autism are able to use context to infer the correct pronunciation of a word (Frith & Snowling, 1983). Homographs are words that consist of the same spelling but have two different pronunciations and definitions.

For example, *lead* can be interpreted as either *lead* in a pencil or as *lead* a group of followers. In this task, children are first presented with a sentence that provides a context that limits the homograph to only one correct pronunciation. Across multiple

studies, children and adults with autism, ranging from 8 to 28 years of age, make more errors on homographs due to failure to consider the context in which it is presented (e.g., Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999; Lopez & Leekam, 2003).

In contrast to these findings, one study found that young children with autism, ranging from 7 to 12 years of age, were able to use context to determine the correct pronunciation of the homograph (Hala, Pexman, & Glenwright, 2007). However, subsequent performance on the Homograph task found significant differences between the autism group and the verbal-age matched typically developing group in the pronunciation of a second homograph. The autism group failed to use context when presented with the homograph a second time, and rather continued with the pronunciation they used when they first saw the homograph. Thus, it seems that children with ASD were able to use the context initially; however, they had difficulty shifting their understanding of the homograph once the context changed. Even though most evidence from the homograph task illustrates that individuals with ASD exhibit strong biases against using context when processing words, the latter study demonstrates that the ability to use context may be moderated by other cognitive functions, such as cognitive flexibility.

Beyond single word processing, WCC theory has also been evaluated with local and global processing at the sentence level. The Sentence Completion Task (Booth & Happé, 2010; Happé, 2000; Happé, et al., 2001) presents the initial part of a sentence and requires the child to provide an appropriate ending. For example, the experimenter reads

to the child, “*The sea tastes of salt and _____*”, and then asks the child to complete the sentence. This presentation allows for an unbiased response from the child and the response can be categorized as referent to the local or global properties of the sentence.

For example, a local response would only take into account the preceding word, *salt*, and such the child may end the sentence with *pepper*. This response would fail to consider the initial context provided in the statement. A global response would consider the context of the sea into the ending statement and result in a response such as *water*. Higher completion scores indicate greater use of context in sentence endings and lower completion scores indicate greater use of the local referent. Evaluations with typically developing individuals between 8 and 25 years of age indicate that older individuals provided more contextually appropriate sentence endings than younger individuals, however, age, IQ scores and gender did not account for 95% of the variance in completion scores. These results indicate that performance on local and global processing as evaluated by the Sentence Completion Task may depend on individual differences rather than attributable to cognitive ability in typical development.

However, comparisons between individuals with ASD and age- and IQ-matched controls found that individuals with ASD had lower completion scores (i.e., less use of global context) and a higher number of local completions than controls. Further analysis showed that full-scale IQ was positively correlated to completion scores, but only for individuals with ASD. The correlation between IQ and completion scores reveals that individuals with ASD may be using compensatory strategies when using global or contextual cues when completing the Sentence Completion Task (Booth & Happé, 2010).

Other studies have explored inferencing abilities in autism as a measure of WCC. The use of inferential tasks to evaluate WCC theory provides another means to evaluate children's cognitive biases, as it is necessary to consider contextual information (i.e., details) to understand meaning (Cook, Chapman & Gamino, 2007). Using a story comprehension task, Norbury and Bishop (2002) presented children between 6- and 10-years of age with a series of questions that required inferring from the provided contextual cues. Children were then separated into three categories based on specific phenotypic presentations of their language difficulties: Specific Language Impairment (SLI), Pragmatic Language Impairment (PLI), and High-Functioning Autism (HFA). The HFA group was determined by parent-report and behavioral observations on standard diagnostic measures (i.e., Social Communication Questionnaire; Berument, Rutter, Lord, Pickles, & Bailey, 1999; Autism Diagnostic Observation Schedule-Generic; Lord et al., 2000).

Children's responses across all questions were then categorized as either good or poor inferencing. In the HFA group, more children were categorized in the poor inferencing group than children in the PLI and SLI groups. When further evaluating the performance of children with PLI, Norbury and Bishop found that all children with PLI who were categorized in the poor inferencing group exhibited symptoms that corresponded with the autism spectrum. Although this relationship was not explored in the SLI group, it provides insight into the possibility that autism symptoms and the inability to integrate details with context may be driven by similar mechanisms. This study will consider autism traits in understanding children's cognitive biases.

Limitations of Weak Central Coherence Theory

Although most studies evaluating children's local and global processing of information have yielded some positive results, many questions remain. A central limitation to WCC theory lies in the processing of global information. The original propositions of WCC theory posit that individuals with ASD fail to process contextual information and meaning, although evidence supporting this proposition is not consistent. For example, studies have found intact global processing in ASD (e.g., Caron, Mottron, Berhiaume, & Dawson, 2006; López & Leekam, 2003; Mottron, Burack, Stauder, & Robaey, 1999; Mottron et al., 2003; Ozonoff, et al., 1991; Ropar & Mitchell, 1999; 2001), while other studies have found that individuals with ASD can process global or contextual information if provided with cues or prompts to do so (e.g., López, Hadwin, Donnelly, & Leekam, 2004; Plaisted, et al., 1999; Snowling & Frith, 1986).

Another concern is the proposal that strength at processing details should correspond to a weakness in processing meaning. This is based on the idea that if the focus is primarily on the individual details, the overall meaning will be neglected due to limited processing (Happé & Booth, 2008; Lopez, 2008; White et al., 2009). Evidence supporting this proposal should show that individuals who are adept at processing details should also demonstrate a weakness in understanding meaning. However, Loth, Gómez and Happé (2008) found that WCC profiles in children, adolescents, and adults with ASD were not uniform and varied across visuospatial and linguistic tasks. Whereas some individuals exhibited greater local processing and weaker global processing across both

visuospatial and linguistic tasks, some individuals with ASD only displayed this pattern in visuospatial or linguistic tasks alone.

The inconsistent patterns were evident across all levels of functioning of individuals with ASD, as the sample ranged in verbal intelligence scores on the Wechsler scales from 56 to 116. Based on this work, further evaluations are needed to examine the conditions under which children with ASD process local and global information, across both visuospatial and linguistic domains. Thus far, most evidence for WCC theory has come from studies tapping into the visuospatial or linguistic domain, however, if children with ASD do not display similar performance patterns across domains (i.e., low or high performance across both visual and linguistic tasks), much information can be lost. This study will incorporate both visuospatial and linguistic measures to assess WCC to gain a more complete understanding of local and global processing in children with ASD.

Systemizing Theory

Alternatively, Systemizing Theory proposes that individuals with ASD are guided by the regularities in their surroundings and are proficient at understanding consistent relationships between these regularities (Baron-Cohen, 2002; 2008; 2009a). Under this theory, individuals with ASD view and analyze information or behaviors systematically and are driven to create systems. To systemize one must initially observe the *Input*, understand its *Operation*, or the rules by which the *Input* functions, and finally arrive at the predicted *Output*. By following these steps, individuals can reliably predict change (Baron-Cohen, 2006).

For example, understanding weather patterns requires a level of systemizing to reliably predict temperatures and precipitation (Baron-Cohen, 2008; Baron-Cohen, Wheelwright, Lawson, Griffin, & Hill, 2007). Systemizing has been proposed as the cognitive drive for repetitive (“stimming”) behaviors, obsessions, and resistance to change often used as part of the diagnostic criteria for ASD (Baron-Cohen, 2006; Baron-Cohen & Wheelwright, 1999; Gomot et al., 2006; Wheelwright & Baron-Cohen, 2011). To date, most studies evaluating systemizing have focused on adult populations and later adapted the relevant findings for children. As this study is interested in understanding systemizing behaviors in children, only the relevant child literature will be reviewed.

Systemizing in children. Initial assessments of systemizing ability used behavioral observations of activities and preferences of children with ASD. The Systemizing Quotient-Child Version (SQ-C) is a 28-item parent-report measure that inquires about children’s behaviors and activities that represent tendencies to systemize (Auyeung, Wheelwright et al., 2009). It has been used to evaluate behaviors and activities in 4- to 11-year olds across typical development and children diagnosed with autism or Asperger Syndrome/high-functioning autism. Some items of the SQ-C include, “*My child enjoys arranging things precisely (e.g., flowers, books, music collections)*” and “*My child enjoys physical activities with set rules (e.g., martial arts, gymnastics, ballet, etc)*” (Auyeung, Wheelwright et al., 2009). The SQ-C provides a systemizing score that represents the individual’s affinity for systemizing in their day-to-day activities and interests, with a higher score indicating a strong systemizer and a lower score indicating a poor systemizer (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003).

Current studies using the SQ-C have found evidence for a continuum of systemizing abilities in children, with typically developing girls scoring lower than typically developing boys and both scoring lower than boys and girls with ASD (e.g., Auyeung et al., 2006, 2009). Scores on the SQ-C have also been positively associated with fetal testosterone levels in typical development (Auyeung et al., 2006) and levels of fetal testosterone have been positively associated with autism symptoms in children with ASD (Auyeung, Baron-Cohen et al., 2009). The direction of these relationships have yet to be disentangled, but may provide an early tool in identifying children at risk for ASD.

Support for systemizing in children with ASD is also evident in direct child measures such as the Picture Sequencing Test and the Intuitive Physics Test. The Picture Sequencing Test (Baron-Cohen, Leslie, & Frith, 1986) presents the child a series of picture stories that need to be organized into a correct sequence. The picture sequences present three types of relationships: mechanical, behavioral, and intentional. A mechanical relationship, for example, would include an individual physically acting on an object, such as pushing a rock. An example of a behavioral relationship consists of individual behaviors, such as an individual getting dressed. An intentional relationship requires understanding mental states, for example, an individual is unaware that another has taken their candy from a box.

Successful performance on this task depends on the child's ability to infer the causal relationship between each picture. Assessments using the Picture Sequencing Test have found that accurate sequencing in children with ASD depends on the type of relationship depicted. In comparison to typically developing children and children with

Down's syndrome, children with ASD were better able to sequence pictures that depicted mechanical and behavioral relationships (Baron-Cohen et al., 1986). Children with ASD performed worse than typically developing controls and children with Down's syndrome on sequencing relationships depicting intentional or mental states. This finding supports the claim that children with ASD have greater systemizing abilities when compared to controls, if not confounded by the need to understand mental states.

Another measure used to assess systemizing ability is the Intuitive Physics Test (Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001). To excel on this measure, the individual must possess knowledge about the physical properties of objects and understand causal relationships between objects. In this study, the principles of physics had not been part of children's school instruction, thus successful performance on this task would be indicative of an ability to adapt previous knowledge of physical objects to solve these problems. Children with Asperger Syndrome of normal intelligence, ranging from 8 to 14 years, showed superior performance on this measure when compared to typically developing children (Baron-Cohen et al., 2001). Based on these findings, it is evident that children with ASD and related diagnoses possess a greater ability to understand systematic relationships when compared to typically developing children.

Limitations of Systemizing Theory

The main limitation of Systemizing Theory is the lack of empirical evidence in system acquisition and usage in children with ASD. To date, systemizing in children has only been evaluated by parent observation (i.e., Systemizing Quotient-Child Version;

Auyeung, Wheelwright et al., 2009), or by cause-effect processing of pictures and objects (i.e., Picture Sequencing Test, Intuitive Physics Test; Baron-Cohen et al., 1986; Baron-Cohen, Wheelwright, Spong et al., 2001). These measures, however useful, do not provide vital information in understanding if children with ASD exhibit a preference for systemizing when faced with multiple correct alternatives.

By using both parent-report and child performance measures of systemizing, this study can offer evidence for the validity of assessing systemizing in children with and without ASD, as well as provide an avenue to explore the relationships of systemizing ability with other cognitive factors (e.g., language ability, central coherence, and executive functioning). Exploring these relationships can be advantageous in determining the best means to shape intervention strategies for efficient learning and generalization of academic, social, and adaptive skills.

Merging Theories: Weak Central Coherence and Systemizing.

Together the WCC Theory and Systemizing Theory may adequately account for the cognitive and behavioral styles exhibited by children with ASD. The underlying premise of these theories concentrates on the functional nature of cognitive abilities in ASD rather than a fixation on the limitations or challenges. Examining the cognitive biases in children with ASD and typically developing children can help modify existing views of learning mechanisms. Baron-Cohen and Belmonte (2005) propose that the early biases for details as delineated by the WCC Theory can essentially facilitate the acquisition of rule-based systems for processing information. It is necessary to approach new information with an analytical frame to adequately tease apart details that may or

may not comprise the system (Baron-Cohen, 2006). To arrive at consistent rules or patterns, the individual must analyze all individual components that could be relevant to the system; therefore, having an acute eye for detail would facilitate this process (Baron-Cohen, 2008; Baron-Cohen et al, 2007).

Evaluations of interventions have found the most successful are those that are highly structured and place emphasis on the process of learning over rote memorization of information (National Research Council, 2001). Systematic approaches are currently being implemented in teaching socio-emotional understanding to children and adults with ASD with optimistic results (e.g., Baron-Cohen, Golan, Wheelwright, & Hill, 2004; Golan & Baron-Cohen, 2006; 2008). If systematic approaches are useful in teaching adults with ASD socio-emotional understanding, these approaches may also be utilized in teaching general knowledge and life skills to children with ASD. Therefore, understanding if the relation between local- and rule-based processing exists in children with ASD is important as this may provide a basis for utilizing system-based approaches in developing intervention programs for children with ASD.

Evidence for the association between local processing and systemizing has only been assessed in adults (e.g., Billington, Baron-Cohen, & Bor, 2008; Spek, Scholte, & Van Berckelaer-Onnes, 2010). A study evaluating neurotypical adults found that scores on the adult version of the Systemizing Quotient were strongly related to their local processing in the Navon task. Regardless of gender, individuals with higher Systemizing scores displayed greater biases towards the local features of the Navon task (Billington et al., 2008). Another study found that Systemizing Quotient scores were strongly

correlated to individual's scores on the Block Design subtest, another measure indicative of local processing in neurotypical adults and adults with high functioning autism/Asperger Syndrome (Spek et al., 2010). It remains unclear whether the relation between local processing and systemizing will be supported in young children, particularly children with ASD. However, the present study will assess the relation between local processing in visuospatial and linguistic tasks and systemizing preferences and ability.

Another area where WCC and Systemizing Theory may combine as a cognitive account for ASD is in language functioning. Evaluations of WCC have suggested that some children with ASD who demonstrate echolalia and hyperlexia may be processing linguistic components at the local or detail level, with comprehension of linguistic material rather limited (e.g., Lord & Paul, 1997; Loveland & Tunali-Kotoski, 1997; McEvoy, et al., 1988; Newman, et al., 2007; Saldaña, Carreiras, & Frith, 2009; Schuler, 2003). Furthermore, Systemizing Theory proposes that children with autism will exhibit difficulties in acquiring and producing functional language (Baron-Cohen, 2006). When learning language, children with ASD will seek out lawful systems; however, considering the many exceptions within language structure and meaning, children with ASD experience difficulty establishing concrete rules to follow.

Recent prevalence rates of ASD indicate that the incidence of ASD does not vary between languages of deep and shallow orthographies (e.g. Center for Disease Control, 2012; Gillberg, Cederlund, Lamberg, & Zeijlon, 2006; Honda, Shimizu, Imai, & Nitto, 2005; Magnússon & Sæmundsend, 2001; Wong & Hui, 2008). Although the prevalence

of children with ASD is similar across linguistically diverse cultures, with rates ranging from 1 in 86 to 1 in 833, the language difficulties may manifest in different ways. The inconsistency with English language structure, form, meaning, and usage creates a difficult medium for children with ASD to engage in communication, particularly if being driven by local features or set rules. This rationale provides support for the rigidity of language in children with ASD (e.g., Boucher, 2003; Groen et al., 2008; Jarrold et al, 1997). The present study will use a standardized language measure (i.e., Clinical Evaluation of Language Fundamentals), central coherence (i.e., Children's Embedded Figures Test; Sentence Completion Task), and systemizing measures (i.e., Systemizing Quotient-Child Version; Picture Sequencing Test) to explore the cognitive factors that could underlie the well-established language difficulties in ASD.

Although the developmental relationship between local/detail processing and systemizing poses a viable link between WCC Theory and Systemizing Theory, they fail to converge on the processing of holistic information in children with ASD. Whereas WCC Theory indicates that children with ASD do not readily process information globally, Systemizing Theory counteracts that children with ASD can process information globally, but only if this information is based on rules or regular patterns that can be easily extracted (Baron-Cohen et al., 2007). The distinctions between the central mechanisms driving global processing in ASD have yet to be explored. This study will utilize a new measure to determine the conditions under which children with ASD encode and process global information. The comparisons between WCC and Systemizing Theories provide opportunities for further investigation. Considering the role of

executive function can be pivotal in evaluating the shifts between local and global processing predicted by the WCC and Systemizing Theories.

Role of Executive Function

Executive functioning has been implicated as playing a crucial role in the cognitive and behavioral presentations in children with ASD. The Executive Dysfunction theory posits that symptoms of ASD parallel the symptoms of frontal lobe dysfunction, such as lack of impulse control, perseverative tendencies, and an inflexibility to change and thus may be subject to similar neural processes (e.g., Hill, 2004; Ozonoff et al., 2004; Pennington & Ozonoff, 1996; Rajendran & Mitchell, 2007). Studies evaluating executive functioning in ASD, however, have yielded conflicting results due to the definitions and methods employed (e.g., Happé, Booth, Charlton, & Hughes, 2006; Hill, 2004; Hughes et al., 1994; Joseph, McGrath, & Tager-Flusberg, 2005; Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009; Russo et al., 2007).

Some studies have found that sub-domains of executive functioning (i.e., inhibitory control, cognitive flexibility) are related to specific symptoms of the ASD diagnosis. For example, repetitive behaviors in individuals with ASD have been associated with the individual's inhibitory control (e.g., Mosconi et al., 2009; Zandt, Prior, Kyrios, 2009). It has been suggested that when children with ASD demonstrate difficulties in inhibition tasks such as the Windows Task or Detour-Reaching Task, it may be due to an inability to understand arbitrary rules and this drives the observed differences when compared to typically developing children (e.g., Hill, 2008; Jones, Webb, Estes, & Dawson, 2013; Russell, 2002). If children with ASD are approaching

these tasks with a systemizing lens, this may explain the observed difficulties in following rules that are arbitrary and not predictable. It is vital to disentangle the cognitive processes children employ when completing executive function tasks, particularly if these processes are connected to cognitive biases in children with ASD.

Even more so, the associations between EF and CC are tenuous. As previously stated, Pellicano, Maybery et al., (2005) found that executive functioning was positively related to visuospatial construction abilities in typically developing preschoolers (4-5-year olds). However, in children with ASD, executive function as measured by perseveration on the Wisconsin Card Sorting Test was not associated with disembedding tasks (e.g., South, Ozonoff, & McMahon, 2007). The latter study, however, only used visuospatial tasks to evaluate CC. Understanding the role of EF in ASD in line with current cognitive theories is important, as it has been found to relate to adaptive behaviors in children with ASD (e.g., Ozonoff, et al., 2004). To gain a greater understanding of potential relationships between EF, CC and Systemizing, parent-reports of daily executive functioning and children's cognitive flexibility will be measured in the current study in conjunction to visuospatial (e.g., Children's Embedded Figures Test; Witkin, et al., 1971) and linguistic (e.g., Sentence Completion Task; Booth & Happé, 2010) CC tasks and systemizing measures (e.g., Systemizing Quotient-Child Version; Auyeung, Wheelwright, et al., 2009; Picture Sequencing Test; Baron-Cohen, et al., 1986).

Current Aims & Hypotheses

The current project will integrate three promising cognitive theories of ASD: WCC, Systemizing, and Executive Dysfunction Theories. WCC Theory proposes that children with ASD focus on details or local information and exhibit difficulties in deriving meaning and processing global information. Systemizing Theory proposes that children with ASD process information in terms of systematic rules or predictable relationships and process global information in this way. Executive Dysfunction theory may account for the mechanisms biasing children's performance on cognitive bias tasks. The present study will add to the existing body of research by addressing the following questions:

- 1) Are there group differences on local processing and systemizing behaviors between HFA, AS, and TD children? What is the relationship between children's ability to process local information and systemizing behaviors in typical and atypical development?
- 2) Do systemizing abilities predict general language ability in children with ASD?
- 3) Under which conditions do children with ASD exhibit a bias for global/contextual or rule-based information?
- 4) Is there a relationship between parent-reported autism traits and children's cognitive biases (local or rule-based processing)?
- 5) Is children's executive functioning related to local processing and systemizing ability?
- 6) Does performance on local processing and systemizing tasks follow distinct developmental trajectories across typical and atypical populations?

Hypotheses

Hypothesis 1: It is expected that there will be significant differences in local processing and systemizing abilities between ASD and TD children. It is also expected that there will be a positive relationship between local information processing and systemizing ability based on the standard measures used in this research (i.e., Children's Embedded Figures Test (CEFT), Sentence Completion Task (SCT), Systemizing Quotient-Child Version (SQ-C), and Picture Sequencing Test (PST)). This means, higher accuracy scores and faster response times on the Children's Embedded Figures Test and higher local processing scores on the Sentence Completion Task will be positively related to higher systemizing scores on the Systemizing Quotient-Child Version and higher accuracy scores on the Picture Sequencing Test. It is expected that this relationship will be stronger within the ASD group than the TD control group. Systemizing Theory posits that systemizing (i.e., understanding predictable relationships) depends on attention to detail, thus, it is expected that across typical and atypical development, attention to detail (i.e., local coherence) will be positively related to systemizing ability. If children's ability to focus on details is related to their understanding of rule-based systems, educators and professionals may capitalize on the importance of details to bridge higher level concepts.

Hypothesis 2: It is expected that greater systemizing ability will predict lower core language scores and standard measures of systemizing abilities used in this study (i.e., SQ-C and PST) for children with ASD. Children with ASD with higher systemizing scores on the SQ-C and higher accuracy scores on the PST will have lower scores on the

Core Language Composite Score of the Clinical Evaluation of Language Fundamentals Test (CELF-4; Semel, Wiig, & Secord, 2003). Children with ASD who demonstrate greater systemizing abilities may have difficulty understanding and producing language due to inconsistencies in language rules. If a negative relationship is found between systemizing ability and core language in children with ASD, it would not only provide a greater understanding of the factors associated with poor language in ASD, but also provide alternative approaches to teaching functional language to children with ASD. Language abilities in ASD have not been previously assessed in conjunction with systemizing measures, therefore this study will yield new information about the underlying factors that contribute to the language difficulties often exhibited in ASD. The negative relationship between language and systemizing is not expected in typically developing children.

Hypothesis 3: It is expected that children's cognitive biases will differ between typically developing children and children with ASD as measured with the Counterfactual Reasoning Task. It is expected that there will be a difference between global/contextual responses and rule-based responses in the Counterfactual Reasoning Task between ASD and TD children. Children with ASD will provide a higher proportion of rule-based responses whereas TD children will provide a higher proportion of global/contextual responses. This will provide the first direct evidence of global and rule-based cognitive biases within the same measure and will demonstrate whether children with ASD can process holistic information by following previously established rules or use the provided context. If, however, children with ASD use contextual

information, this will provide an avenue to teach social cognition, as understanding meaning has been suggested to be necessary for social cognition (e.g., Booth & Happé, 2010). This can provide pivotal support in the merging of WCC and Systemizing Theories and can be informative in formulating strategies for children with ASD to acquire and generalize new behaviors and social cognition.

Hypothesis 4: It is expected that parent-reported autism traits/behaviors will demonstrate a strong positive relationship to cognitive biases in children with ASD. First, it is anticipated that parent-reported autism behaviors will be positively related to local processing and systemizing ability in children with ASD and TD children. Higher scores on the Autism Spectrum Quotient will correlate with higher local processing scores on the Children's Embedded Figures Test, Sentence Completion Task, and higher systemizing scores on Systemizing Quotient-Child Version and Picture Sequencing Test for the ASD and TD groups.

Hypothesis 5: It is anticipated that executive functioning as measured via parent-report and a cognitive flexibility task in children with ASD, will be associated with local coherence and systemizing ability. Less intact executive functioning will be represented by high scores on the Behavior Rating Inventory of Executive Functioning (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) and lower perseverative error scores on the Wisconsin Card Sorting Test (WCST; Kongs, Thompson, Iverson, & Heaton, 2000). If children with ASD exhibit less intact executive functioning, this may contribute to difficulties in switching between local and global processing. This finding will provide support that executive functioning serves an important role in cognitive biases in children

with ASD. Understanding the significance of executive functioning in how children with ASD process new information will offer specific information in supporting learning environments for children with ASD.

Developmental Trajectory Approach

Understanding differences and similarities in task performance between children with ASD and TD children is challenging when observing distinct cognitive biases. The evaluation of individuals with ASD becomes difficult when understanding how their performance on cognitive and behavioral measures maps onto established normative data. Burack et al., (2004) outlined three main issues when evaluating children with ASD that are essential to consider prior to establishing a matched comparison sample.

The first issue to consider is inherent in the defining characteristics of ASD, the peaks and valleys of abilities across cognitive, linguistic, and social domains. Due to the unbalanced performance profiles in ASD, it is difficult to match participants based on their performance on a specific measure, such as receptive vocabulary, nonverbal reasoning, or IQ. Although the individual with ASD is matched on established criteria to another individual, there may be discrepancies, small or large, in another domain that may affect the measure of interest. Of particular concern is the practice of “covarying” language or other cognitive ability when comparing children with ASD with TD children. These methods attempt to account for underlying differences; however, they may inevitably remove the “autism” that characterizes the very group one is interested in assessing (Charman, 2004; Joseph et al., 2005). Therefore, any results that arise may be

artificial and not indicative of true differences or similarities between ASD and TD children.

The second issue that arises when evaluating children with ASD is the wide range of intellectual functioning encompassing this population. The heterogeneity of functioning in ASD increases the challenges in matching with typical development on chronological and mental age. Past studies assessing children with ASD have commonly used younger children to accommodate matching by mental age, however, this matching strategy introduces other concerns related to the task of interest. The third issue when evaluating children with ASD concerns the distinct experiences children with ASD have that may shift their developmental trajectories away from typical development. Although children with ASD may process information in similar ways to TD children, the experience of interventions and specialized education plans may alter the performance patterns observed. These issues are central to any claims and conclusions that are drawn from studies matching samples of TD children and children with ASD.

To account for issues in using matched comparison groups, Thomas et al. (2009) have proposed the Developmental Trajectory Approach to analyze performance profiles in understanding whether the profiles found in developmental disorders overlap or deviate from profiles found in typical development. This approach utilizes children's mental or chronological age as a basis for comparing trajectories of task performance between groups (i.e., typically developing group and disorder group). The trajectories can be compared to detect delayed onset, slowed rate of development or both by comparing the disorder group to a compatible typically developing sample (i.e., within

the same range in chronological age or mental age). This method is particularly useful in determining if performance on a given task is delayed, disordered or follows a non-linear progression. To understand how children with ASD perform on measures of local and global processing, systemizing, language and executive functioning, the Developmental Trajectory Approach will be utilized as the method of analyzing and comparing children's performance.

Autism Spectrum Disorder Group

To best evaluate cognitive biases in children with ASD, it will be necessary to specify eligibility criteria for children with ASD. Due to the heterogeneity of abilities in ASD, eligibility criteria will ensure that children with ASD will be able to understand directions and provide an adequate portrayal of their true abilities. In consideration of previous studies employing the measures to be used in the current study, the ASD group will be comprised of children with diagnoses of high-functioning autism (HFA) and Asperger Syndrome (AS) between 7 and 11 years of age. The inclusion of these two groups was based on the specific diagnostic criteria outlined by the DSM-IV-TR (American Psychiatric Association, 2000), therefore it is believed that participants within each group will present a more homogenous sample. Children with PDD-NOS were not included because it was believed that they would comprise a more heterogeneous group based on the various symptomatology that would result in a PDD-NOS diagnosis. This age range and group inclusion will provide a developmental timeframe to evaluate differences in cognitive bias across maturation in middle childhood.

CHAPTER TWO

METHODS

Participants

Two groups of children were included in this study: a typically developing group and a group of children with Autism Spectrum Disorder (ASD). Typically developing children and children with ASD were evaluated on nonverbal reasoning and core language measures to ensure performance within normal limits. Assessing nonverbal reasoning and language skills was necessary to determine if the child would be able to understand and follow instructions for the tasks included in the study.

Autism Spectrum Disorder Group

Children with ASD were eligible to participate if they were between 7 and 11 years of age, had an overall IQ of 70, and performed within the standard norms of nonverbal reasoning and core language measures. This criteria ensured that children with High-Functioning Autism (HFA), Asperger Syndrome (AS), and Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS) would not only understand their rights as a participant (i.e., voluntary participation, right to withdraw, confidentiality of responses), but also be able to answer questions and provided responses for the measures included in this study. Children's diagnoses were confirmed by parent report on the Child Information Form (Appendix A). The ASD group sample included

25 children with ASD, 11 with HFA, 11 with AS, and three with PDD-NOS. Due to the small sample size for the PDD-NOS group and the possibility that they may perform differently than the HFA and AS groups, they were not included in the analyses. The final sample included 19 males, and three females, 77% were European American, 5% were African American, and 18% were of mixed racial background. Children with ASD, who were eligible, had parent consent and provided assent, completed all measures included in this study.

Typically Developing (TD) Children Group

Children were eligible to participate if they were between 7 and 11 years of age and had not been diagnosed with learning disabilities (e.g., dyslexia, language impairment) or neurological disorders (e.g., ADHD, Tourette's syndrome, epilepsy). This was determined through parent report on the Child Information Form located in Appendix A. The control group included 25 typically developing children, 18 males and 7 females (Mean age = 9 years, 0 months), 80% were European American, 5% were Asian American, and 16% were of mixed racial background. By using the Developmental Trajectory Approach, children's performance was compared across the full range of abilities between both groups (Thomas et al., 2009). Once it was determined the child met eligibility criteria, testing sessions were scheduled with the child's school and/or parent. TD children in the control group completed all measures of the study described below, if parent consent and child assent was obtained. A description of all measures collected is also included in Appendix B and C.

Recruitment

After receiving approval from the Loyola University Chicago Institutional Review Board, children were recruited from a variety of sources. Flyers with study information were posted in public libraries across the greater Chicago area. Directors of clinics, schools, and community organizations were also contacted to distribute a letter describing the research study to eligible families. ASD participants were recruited with the assistance of the Interactive Autism Network (IAN) Research Database at the Kennedy Krieger Institute and Johns Hopkins Medicine – Baltimore, sponsored by the Autism Speaks Foundation. TD children were also recruited from an existing database of research study participants at Loyola University. Parents had provided consent to be contacted about future research studies and were mailed a letter describing the research study. Contact information was provided so interested parents could contact the principal investigator for more information, questions, or concerns. The Child Information Form inquired about children's basic medical, developmental, and educational history. The information collected on this form was used to determine if the child was eligible to participate in the study, as well as provide valuable background information about children who were eligible.

Measures

Autism Traits and Behaviors

Children's autism traits and behaviors were evaluated using the Autism Spectrum Quotient- Child Version (ASQ-C; Auyeung, Baron-Cohen Wheelwright, & Allison, 2008). This questionnaire was adapted from the adult and adolescent versions and

formulated as a parent-report as self-report in children may be constrained by reading and comprehension difficulties. This questionnaire inquired about children's behaviors and interests that map onto the diagnostic criteria for ASD as outlined by the triad of impairments (APA, 2000; Rutter, 1978; Wing & Gould, 1979). The ASQ-C has been standardized with both typical and atypical child populations from 4 to 11 years of age and presents 50 statements across five domains: *Social skills, attention switching, attention to detail, communication* and *imagination*. This parent-report measure has been used extensively to evaluate the presence of autism traits in typically developing children and children with ASD (e.g., Auyeung, Baron-Cohen, et al., 2009). Therefore, this measure was appropriate in providing a quantitative measure of autism traits and behaviors to determine the relationship between autism traits and cognitive biases. The ASQ-C was not used to diagnose any children participating in this study.

Each item required the parent to indicate their level of agreement on a Likert scale with the following descriptions: *Definitely Agree, Slightly Agree, Slightly Disagree*, and *Definitely Disagree*. Each item was then given a score ranging from 0 to 3, based on how characteristic the item was to an autism diagnosis. For example, the item "*People often tell her/him that s/he keeps going on and on about the same thing,*" would receive a score of 3 if the parent selected *Definitely Agree*, but would receive a score of 0 if the parent selected *Definitely Disagree*. The maximum score attainable was 150 with a minimum score of 0. The total questionnaire poses an internal consistency of $\alpha = 0.97$ and test-retest reliability of $r = 0.85, p < 0.001$. The standardization of the questionnaire yielded high specificity of 95% and high sensitivity of 95% based on a cutoff score of 76 in

identifying children with autism (Auyeung et al., 2008). Children's total scores on the ASQ-C were used to evaluate how autism traits related to children's cognitive biases. To avoid bias in parental responses, Auyeung and colleagues labeled the questionnaire as the *Cambridge University Behaviour and Personality Questionnaire for Children*. This format was followed in the present study and was also completed by parents of typically developing children and children with ASD. The ASQ-C is included in Appendix D.

Nonverbal Reasoning

To assess nonverbal reasoning, the Raven's Standard Progressive Matrices was used (Raven's SPM; Raven, Court, & Raven, 1992). The Raven's SPM has been widely used to assess nonverbal reasoning in typically developing children and children with learning differences (e.g., ASD, reading disorders, specific language impairment, Down's syndrome; Norbury & Bishop, 2002; Pickles et al., 2009; White et al., 2006). The Raven's SPM presents a series of 60 patterned images and requires the child to select the appropriate image that completes the pattern. The Raven's SPM yields a raw score and percentile rank of the child's performance based on the number of patterns completed correctly and national age norms. Internal consistency for the items on the Raven's SPM is high, ranging from $\alpha = .97 - 1.00$ and a test-retest reliability of $r = .88$. Total time to complete the task was also recorded. This measure took approximately 20 minutes to complete.

Language Ability

Children's language abilities were assessed using the Clinical Evaluation of Language Fundamentals – 4th edition (CELF-4; Semel et al., 2003). The CELF-4 is an

assessment tool that evaluates children's language strengths and weaknesses, as well as the underlying processes (e.g., working memory, phonological awareness), and the contextual implications of their language abilities (e.g., effects on school performance). The CELF-4 provides a Core Language Score comprised of general ability subtests that discriminate between typical and disordered language performance. The CELF-4 has been used extensively to evaluate specific and general components of language functioning in children with ASD (e.g., Kjelgaard & Tager-Flusberg, 2001; Leyfer, Tager-Flusberg, Dowd, Tomblin, & Folstein, 2008; Lloyd & Paintin, 2006; Rapin, 1996; Tager-Flusberg & Cooper, 1999; Tomblin & Zhang, 1999). Test-retest reliability for composite CELF-4 scores is high, $r = .90+$ and internal consistency ranges from $\alpha = .89 - .95$. In the current study, children's Core Language Score was assessed using receptive and expressive language subtests predetermined by the child's age. Children between 7 and 8 years completed the following four subtests: Concepts and Following Directions, Word Structure, Recalling Sentences, and Formulated Sentences. Children between 9 and 11 years of age completed the following four subtests: Concepts and Following Directions, Recalling Sentences, Formulated Sentences, and Word Classes 1 and 2. The CELF-4 subtests took approximately 30 minutes to complete.

Executive Functioning

Based on the recommendations by Hill (2004) and Kenworthy, Yerys, Anthony, and Wallace (2008) for the necessity of using comprehensive measures of children's executive functioning in the lab and in the home, parent-report and direct child evaluations of executive functioning were obtained to capture a more complete picture of

children's executive functioning skills. This provided a greater understanding of how children's executive functioning skills in the home and in experimental tasks relate to local, global, and rule-based processing in children with ASD and typically developing children.

Children's general executive functioning skills were evaluated using the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al, 2000) and cognitive flexibility was measured with the Wisconsin Card Sorting Test – 64 Card Version (WCST-64; Kongs, Thompson, Iverson, & Heaton, 2000). The BRIEF is a parent questionnaire that taps into everyday behaviors and activities. The BRIEF consists of 86 items and yields standardized scores across eight subtests (i.e., inhibition, cognitive shifting, emotional control, initiating behaviors, working memory, planning/organization, organization of materials, and monitoring). Each item requires the parent to report the degree each behavior or activity has occurred for their child in the past 6 months. The BRIEF has been used extensively with populations that exhibit difficulties with executive functioning, such as ASD, Attention-Deficit/Hyperactivity Disorder, Tourette's syndrome, learning disorders, frontal lesions, and obsessive-compulsive disorders (e.g., Chan et al., 2009; Christ et al., 2010; Gioia, Isquith, & Kenealy, 2008; Kenworthy et al., 2005; Zandt et al., 2009). The BRIEF presents an internal consistency ranging between $\alpha = .80-.98$, and a test-retest reliability of $r = .82$. The BRIEF took approximately 10-15 minutes for parents to complete.

The Wisconsin Card Sorting Test – 64 Card Version (Kongs, Thompson, Iverson, & Heaton, 2000) was adapted from the original Wisconsin Card Sorting Test (Heaton,

Chelune, Talley, Kay, & Curtiss, 1993). The WCST-64 version was modified to shorten the original 128-card version while still maintaining the same instructions and task demands across the lifespan (i.e., from 6.5 years to 89 years). This measure provided an evaluation of children's cognitive flexibility and has been used to evaluate executive functioning in children with ASD (e.g., Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; López, Lincoln, Ozonoff, & Lai, 2005; Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff & Jensen, 1999; Prior & Hoffmann, 1990). The child was first shown four cards that represented four dimensions across three categories (i.e., color, form, and number) used to match the remaining cards. The child was then instructed to match each card from the stack to one of the four target cards. After 10 consecutive correct responses, the matching category shifted to another category. The experimenter only provided the child with feedback about the correctness of their match. The child was not informed of the matching category currently being used. Testing continued until the child matched all 64 cards. Children's responses for the WCST were scored for perseverative errors based on national norms. Internal consistency reliability estimates range from $r = .60$ to $.85$. The WCST took approximately 10 to 15 minutes to complete.

The inclusion of these two measures of executive functioning provided a more in-depth assessment of executive functioning in children that may not be evident with the use of only one measure. For example, Ozonoff (1995) found that performance on the Wisconsin Card Sort Test is affected by the presence or absence of an experimenter. Furthermore, it is difficult to determine the specific executive functions assessed across tasks, as many require multiple demands of executive control, such as inhibition, working

memory, set-shifting and planning (e.g., Gioia & Isquith, 2004; Kenworthy et al., 2008; Verté et al., 2006). Reviews of the BRIEF have found that interpretation of the subscales may be limited due to the specific nature of the questions (e.g. Schraw, 2003). Based on these issues, including two assessments of executive functioning provided a more adequate measure of children's executive functioning.

Weak Central Coherence

To assess children's CC, two standard tasks were used across the visuospatial and linguistic domains. The Children's Embedded Figures Test (CEFT; Witkin et al., 1971) was utilized to assess CC in the visuospatial domain. Reliability estimates for the CEFT range from $r = .83 - .90$. The CEFT requires children to locate a small figure or shape embedded within a meaningful picture. The images were presented in color on size A5 cardstock and the child was provided with a cardboard cutout of the figure needed to locate (i.e., Tent and House).

Children were first introduced to the figures they would be asked to locate (i.e., Tent and House), followed by training in locating the figures. For the training, the experimenter stated to the child, *"This looks something like a TENT, doesn't it? This black line at the bottom shows where our TENT rests on the ground. See if you can find another TENT that looks exactly like ours on this page"*. After the training, two practice trials for the Tent figure and one practice trial for the House figure will be completed. If the child demonstrated an adequate understanding of the task, the experimenter continued with the trials. Children who exhibited difficulties in locating the figure were instructed

on how the correct location corresponds with figure, despite differences in color and overlapping lines.

For each trial, the experimenter asked the child to locate the figure (i.e., Tent or House) within the colorful pictures. The child received a score of 1 for every correct location identified, for a maximum score of 25 across both the Tent and House stimuli. This task took approximately 20 minutes to complete. Children's scores on the CEFT were recorded for proportion of trials completed accurately and response times across correct trials.

The Sentence Completion Task (Booth & Happé, 2010; Happé, 2000; Happé et al., 2001) was used as the linguistic measure of CC. The Sentence Completion Task presented the child with the initial part of a sentence, followed by a prompt for the child to complete the sentence. The open format of this task allows for an unbiased response, providing insight into how children naturally perceive the sentence. Fifteen sentences (1 practice sentence, 10 test sentences, 4 filler sentences) were presented visually and verbally to lessen the task demands. Each sentence was printed on size A5 (8.3" x 5.8") cardstock paper in size 50 Arial font. As the sentence is presented, the experimenter read the sentence out-loud to the child. If the child needed to hear the sentence again, the experimenter repeated the sentence. These methods minimized potential limitations in assessing young children such as difficulties in reading and/or writing.

Children's processing time was recorded from the time the experimenter finished reading the sentence, to the time the child began their verbal response. Children's verbal responses were recorded by the experimenter on each child's score sheet and were coded

following the 3-point scoring system used by Booth & Happé (2010). Global responses provided within 10 seconds were assigned a score of 2. Global responses provided after 10 seconds, incoherent responses, or when no response was provided received a score of 1. Global responses consisted of sentence completions that took the entire context of the sentence into consideration. Local responses provided were assigned a score of 0. Local responses were determined if the child's sentence completion referred to the last two words of the sentence and did not fit within the context of the complete sentence.

Completion scores were summed across the 10 test sentences for a minimum score of 0 and a maximum score of 20. The completion scores were transformed into overall local processing scores so that higher values indicated a higher level of local processing. Three scores were recorded for each child: overall local processing scores, number of local responses, and response time. Response time was also recorded for the filler items to have a baseline comparison for global and local response times. This task took approximately 10 minutes to complete. The Sentence Completion Task along with an example of the scoring guide is included in Appendix E.

Systemizing

Children's systemizing abilities were assessed using the Systemizing Quotient-Child Version (SQ-C; Auyeung, Wheelwright et al., 2009) and the Picture Sequencing Test (PST; Baron-Cohen et al., 1986). The SQ-C is a 28-item parent questionnaire that evaluates the presence of strong or weak systemizing based on the child's daily behaviors, activities, and interests. The SQ-C has an internal reliability of $\alpha = .78$ and

test-retest reliability of $r = .84$. The questionnaire asked the parent to report their level of agreement with each statement based on a 4-point Likert scale, with the labels *Definitely Agree*, *Slightly Agree*, *Slightly Disagree*, and *Definitely Disagree*.

Each item is scored as 0, 1, or 2 depending on the level of systemizing the item represents. For example, a response of *Definitely Agree* for the item “My child likes to collect things (e.g., stickers, trading cards, etc.)”, would elicit a score of 2, whereas a response of *Slightly Disagree* for the item “My child finds using computers difficult” would elicit a score of 1. The item scores are summed to provide a Systemizing Quotient score. The maximum score on the SQ-C is 56 with a minimum score of 0. The Systemizing Quotient score was used as an indicator of children’s level of systemizing preferences. The Systemizing Quotient – Child Version is located in Appendix F.

The Picture Sequencing Test (PST) was used as a behavioral measure of systemizing (Baron-Cohen et al., 1986). Two conditions depicting mechanical and behavioral systems were used. Each condition consisted of six picture sets and was presented in a random order. All pictures were printed on 4” x 4” cardstock paper in color. For each picture set, three individual images were presented in a random array. The first picture of the sequence was provided to the child. The child was then instructed, “*This is the first picture. Look at the other pictures and see if you can make a story with them.*” If the child does not understand the task, they were given a prompt “*Which is the next picture?*” and instructed to select the picture and place it next to the first picture. The correct sequence of pictures received a score of 2; however, if only the last picture of the sequence was correct, the child will receive a score of 1.

This coding followed the original administration by Baron-Cohen et al. with the intent to discriminate between guessing and correct answers. Each condition could thus have a maximum score of 12 and a minimum score of 0. Accuracy on the Picture Sequencing Test was determined by the total score obtained, divided by the total score possible (i.e., 24). The Picture Sequencing Test took approximately 10 minutes to complete. The Picture Sequencing Test is located in Appendix G.

Global/Contextual vs. Rule-Based Processing

To evaluate whether ASD and TD children exhibit specific biases when processing new information, a counterfactual reasoning task was adapted (Leavers & Harris, 2000; Scott, Baron-Cohen, & Leslie, 1999). This task provided an unbiased platform for children to display their natural tendencies towards global context or rule-based information and enabled comparisons between cognitive biases that have been limited in the past.

The Counterfactual Reasoning Task (CRT) evaluated children's cognitive biases. This task first presented children with eight control questions to determine the child's prior knowledge. If a child was unable to answer a control question correctly, they were provided with the correct answer and asked to repeat the information. Children were then told, "I'm going to read you some stories. Some of the things in the stories may sound a bit funny, but in these stories everything is true." Two conditions were then presented with eight statements for the Real World Condition and eight statements for the Imaginary World Condition. The order of condition was counterbalanced across the ASD and TD group, with about half of each group receiving the Real World condition

followed by the Imaginary World condition, and the other half of children receiving the Imaginary World condition followed by the Real World condition. Within each condition, the order of statements was also presented randomly.

Each statement required interpretations based on the context provided, or previously established rules. Children's responses and explanations were coded as following Context or Rule-based information. Explanations that did not fit into the context of the statement or the rule-based information or incoherent explanations were coded as Arbitrary. Proportions were calculated for context-based and rule-based responses and explanations. Children's scores for this task were used as a measure of children's bias for context or rule-based information. The Counterfactual Reasoning Task took approximately 15 minutes to complete. The control questions and statements for the Counterfactual Reasoning Task (CRT) are included in Appendix H.

Procedures

Interested parents were informed via postal mail, email or phone of all study procedures and the potential to understand children's cognitive biases. If they agreed to allow their child to participate and met eligibility criteria based on the Child Information Form, an appointment was scheduled for the child to participate. All children were tested individually in a separate classroom at the child's school, in the child's home, or in the Child Observation Lab at Loyola University Chicago by a female experimenter. The assessments were administered across one or two days (within two weeks). During the first session, the experimenter explained to the child the purpose of the study and asked the child if they would like to participate. The child was informed of their rights as a

participant, including the confidentiality of their responses and their right to withdraw assent at any time. Once the child indicated they understood and provided assent, the experimenter began the assessment.

All tasks were administered in a random order and included the Raven's SPM, the CELF-4, the Children's Embedded Figures Test (CEFT), the Sentence Completion Task (SCT), the Picture Sequencing Test (PST), the Wisconsin Card Sorting Test-64 Card Version, and the Counterfactual Reasoning Task (CRT). If one session was administered, all tasks took approximately two hours to complete and included a 5-10 minute break at the child's request. If two sessions were administered, the tasks were again administered in random order, with each session lasting about an hour. The child was free to end their participation at any time during the testing and during any testing session. Positive feedback and breaks were also provided to each child to maintain motivation throughout the session. Upon completion of the first session, the child was given a packet of pencils and erasers. Upon completion of the second session, the child was given an age-appropriate book for their participation. If the child completed all measures in one session, they received both the packet of pencils and erasers and a book at the end of the session.

CHAPTER THREE

RESULTS

Preliminary Analyses

Data were analyzed for normality and anomalies, including outliers, extreme scores, and homogeneity of variance. Following guidelines for tests of normality (Tabachnick and Fidell, 2007), a conservative significance value of .01 was used to determine if the distributions for variables of interest were significantly different than a normal distribution. Tests of normality found that accuracy scores for the Picture Sequencing Test were negatively skewed for the HFA group, $D(11) = 0.32$, $p = .003$ but not the AS group, $D(11) = 0.16$, $p = .20$, or the TD group, $D(24) = 0.19$, $p = .031$. Scores for the Counterfactual Reasoning Task were significantly non-normal (positively and negatively skewed) for the HFA group, $Ds(11) > .29$, $ps < .009$, AS group, $Ds(11) > 0.30$, $ps < .008$, and the TD group, $Ds(25) > 0.29$, $p < .001$. Further analyses testing for homogeneity of variance across the HFA, AS, and TD groups found that the variances were significantly different for the Counterfactual Reasoning Task Real World and Imaginary World variables, $Fs(2, 44) > 6.00$, $ps < .005$.

Transforming Violations of Normality and Homogeneity of Variance

Arcsine transformation is recommended when proportion scores (i.e., range from 0 to 1) are found to violate assumptions of normality. In order to meet assumptions of

normality and homogeneity of variance, an arcsine transformation was conducted on the Picture Sequencing Test Accuracy proportion variable for the HFA, AS and TD groups, and on the Counterfactual Reasoning Task context and rule-based responses and explanation proportion variables.

Follow up tests of normality and homogeneity of variance for transformed Picture Sequencing Test Accuracy Proportion Variable. Tests of normality following the arcsine transformation showed that the Picture Sequencing Test Accuracy proportion was significantly different than a normal distribution for the HFA group, $D(11) = 0.31$, $p = .004$. Considering that the HFA group distribution had shifted from a highly negative skew to a moderately negative skew, the arcsine transformed Picture Sequencing Test Accuracy proportion was used in further analyses (Bulmer, 1979).

Follow up tests of normality and homogeneity of variance for transformed Counterfactual Reasoning Task Variables. Additional tests of normality found that the distributions for the Real World and Imaginary World variables for Counterfactual Reasoning Task were still significantly different from a normal distribution for the HFA group, $Ds(11) > 0.32$, $ps < .003$, AS group, $Ds(11) > 0.32$, $ps < .003$, and TD group, $Ds(25) > 0.29$, $ps < .001$. Tests of homogeneity of variance found that the variances for the arcsine transformed Counterfactual Reasoning Task Rule-based responses and explanation scores for the Real World condition between the HFA, AS, and TD groups were no longer significantly different, $Fs(2, 44) < 1.31$, $ps > .279$. Additionally, the variance for Rule-based responses and explanations were found to be significantly different between the HFA, AS, and TD groups for the Imaginary World conditions,

$F(2, 44) > 5.90, ps < .005$. Due to the inconsistent resolution of the arcsine transformation on the normality and homogeneity of variance for the Counterfactual Reasoning Task, the raw data was kept and non-parametric tests were planned for analyses on the Counterfactual Reasoning Task (Field, 2009).

Demographic Data

Overall group means for chronological age, nonverbal reasoning raw scores, and core language scores are displayed in Table 1. Group comparisons were conducted on the HFA, AS and TD groups to determine if the groups were comparable on demographic and preliminary variables. A One-way ANOVA found no significant differences between the HFA, AS and the TD Groups on chronological age, $F(2, 44) = 3.05, p = .06$, nonverbal reasoning raw scores, $F(2, 43) = 0.70, p = .50$, and the number of testing sessions, $F(2, 44) = 1.62, p = .21$. A Pearson chi-square analysis also showed that there were no significant differences in the frequencies of male and females across the HFA, AS, and TD groups, $\chi^2(2, N = 47) = 1.71, p = .43$. This allowed for further analyses as potential differences across tasks could be determined to be unrelated to demographic information and testing manipulations.

A One-way ANOVA also found that there were significant differences in core language scores between the HFA, AS, and TD groups, $F(2, 43) = 22.81, p < .001$. Follow-up t-tests with Bonferroni correction for multiple comparisons determined that there was a significant difference in core language scores between the HFA group and the AS group, $t(20) = -4.43, p < .001$, and between the HFA group and the TD group,

$t(12.98) = -5.35, p < .001$, but not between the AS and TD groups, $t(33) = -0.18, p < .862$ (see Table 1).

Table 1. Mean Chronological Age, Raven's Raw Scores, and Core Language Scores across the Autism Spectrum Disorder (HFA and AS) and Typically Developing Groups

Group	<i>n</i>	Chronological Age ^a		Raven's Raw Score ^b		Core Language Score ^c	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
ASD	22	9.83	1.41	33.05	10.23	90.59	24.39
HFA	11	10.13	1.48	30.64	11.72	73.82	19.90
AS	11	9.53	1.33	35.45	8.35	107.36	15.29
TD	25	9.00	1.17	33.67	9.34	108.17	11.19

Note: ^a – Chronological age is reported in years; ^b – Raven's raw score is based on maximum score of 60; ^c – Core language score has a standard mean of 100 and standard deviation of 15

Due to the differences observed in language abilities between the HFA and the AS and TD groups, further analyses would adopt a “language cautious” approach (Charman, 2004). This pragmatic approach attempts to account for potential differences between the HFA, AS, and TD groups, while maintaining the integrity of the cognitive composition of the HFA and AS groups that can often be lost in analyses of covariance (e.g., Dennis et al., 2009; Miller & Chapman, 2001). Therefore, statistical analyses evaluated the HFA and AS groups separately to account for any underlying differences when compared with the TD group.

Main Analyses

Performance on Local Processing (CEFT, SCT) and Systemizing (PST, SQ-C)

Between HFA, AS, and TD Children

Prior to exploring the relationship between local processing and systemizing in HFA, AS, and TD children, analyses were first conducted to determine if there were any significant differences between groups across these measures. Past studies have reported inconsistent similarities and differences on children's performance. A Multivariate Analysis of Variance was conducted on children's accuracy and response time for the Children's Embedded Figures Test, the overall scores for the Sentence Completion Task, the Systemizing Quotient – Child Version, and the transformed accuracy proportion scores for the Picture Sequencing Test. Results found that there was a significant difference in Children's Embedded Figures Test Accuracy proportion scores between the HFA, AS, and TD groups, $F(2, 42) = 3.93, p = .027$, partial $\eta^2 = .158$. There were no significant differences between the HFA, AS, and TD groups on the Children's Embedded Figures Test Response Time, $F(2, 42) = 2.33, p = .110$, partial $\eta^2 = .100$, Sentence Completion Task Overall Scores, $F(2, 42) = 2.04, p = .142$, partial $\eta^2 = .089$, Systemizing Quotient – Child Scores, $F(2, 42) = 0.50, p = .952$, partial $\eta^2 = .002$, or Picture Sequencing Test Accuracy Proportion, $F(2, 42) = 1.86, p = .169$, partial $\eta^2 = .081$.

Follow-up analyses controlling for multiple comparisons indicated that there was a significant difference in Children's Embedded Figures Test Accuracy proportion scores between the HFA and TD groups, $t(34) = -2.80, p = .008$, $M_{\text{HFA}} = .46$, $SD_{\text{HFA}} = .19$, $M_{\text{TD}} = .64$, $SD_{\text{TD}} = .18$. There was a trend for significance observed between the HFA and AS

groups, $t(20) = -2.04, p = .055, M_{HFA} = .46, SD_{HFA} = .19, M_{AS} = .63, SD_{AS} = .20$.

There was no significant difference between the AS and TD groups, $t(34) = -0.24, p = .814, M_{AS} = .63, SD_{AS} = .20, M_{TD} = .64, SD_{TD} = .18$. The difference in Children's Embedded Figures Test Accuracy proportion scores between the HFA and TD groups indicated that TD children were more accurate in locating embedded figures than HFA children. Group means for the Children's Embedded Figures Test, the Sentence Completion Task, the Systemizing Quotient – Child Version, and the Picture Sequencing Test are shown in Table 2.

Table 2. Mean CEFT, SCT, SQ-C, and PST Scores for the HFA, AS, and TD Groups

	HFA ($n = 11$)		AS ($n = 11$)		TD ($n = 25$)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
<u>Local Processing</u>						
CEFT Accuracy ^a	.46	.19	.63	.20	.64	.18
CEFT RT ^b	8.41	4.99	14.69	10.16	11.77	5.45
SCT Overall	5.45	3.30	3.91	3.39	3.04	2.51
<u>Systemizing</u>						
SQ-C Score	25.18	7.61	26.18	8.91	24.88	10.06
PST Accuracy ^a	.83	.18	.91	.06	.91	.07

Notes: CEFT – Children's Embedded Figures Test, Total possible trials = 25

SCT – Sentence Completion Test, Max score = 20, higher scores indicate higher local processing

SQ-C – Systemizing Quotient – Child Version, Max score = 56

PST Accuracy – Picture Sequencing Test Proportion Correct, Total trials = 12

^a – Accuracy reported as proportion correct

^b – RT – Mean response time in seconds for correct trials

Systemizing Theory proposed that attention to detail was a necessary skill to develop systemizing abilities (Baron-Cohen & Belmonte, 2005). It was expected that

local processing would be positively related to systemizing abilities in HFA, AS, and TD children. Pearson correlations were conducted with the Children's Embedded Figures Test Accuracy Proportion, Children's Embedded Figures Test Correct Trial Response Time, Sentence Completion Task Overall Score, Transformed Picture Sequencing Test Accuracy Proportion, and the Systemizing Quotient – Child Version scores. The correlation analyses were conducted separately for the HFA, AS, and TD groups. Results from the Pearson correlation analyses are presented in Table 3.

Table 3. Pearson Correlations between the CEFT Accuracy, CEFT Response Time, SCT Overall Scores, Systemizing Quotient – Child, and PST Accuracy Across HFA, AS, and TD Groups

Group	<i>n</i>	1	2	3	4	5
HFA						
1. CEFT Accuracy	11	--	.53	-.52	.33	.35
2. CEFT RT	11		--	-.19	-.15	.25
3. SCT Overall	11			--	-.35	-.57
4. SQ-C					--	.39
5. PST Accuracy						--
AS						
1. CEFT Accuracy	11	--	.20	-.12	.42	.59
2. CEFT RT	11		--	-.59	-.14	-.01
3. SCT Overall	11			--	-.15	.10
4. SQ-C					--	.47
5. PST Accuracy						--
TD						
1. CEFT Accuracy	25	--	.37	.10	.39	.18
2. CEFT RT	25		--	.02	-.20	.06
3. SCT Overall	25			--	.29	.39
4. SQ-C					--	.11
5. PST Accuracy						--

Note: 1. CEFT Accuracy – Children's Embedded Figures Test Accuracy Proportion (out of 25)
 2. CEFT Response Time – Children's Embedded Figures Test Response Time for Correct Trials in seconds; 3. SCT Overall Score – Sentence Completion Test Overall Local Processing Score; 4. SQ-C – Systemizing Quotient – Child version Raw Score; 5. PST Accuracy – Picture Sequencing Test Transformed Accuracy Proportion Score

All *ps* = n.s.

Overall, there was no significant relationship between the local processing variables (i.e., Children's Embedded Figures Test Accuracy Proportion and Correct Response Time, and Sentence Completion Test Overall Score) and children's systemizing abilities (i.e., Picture Sequencing Test Accuracy Proportion, Systemizing Quotient – Child Version) for the HFA group, $r_s(11) < .35$, $p_s > .285$, although there was a trend towards significance for HFA children's Sentence Completion Test Overall Score and the Picture Sequencing Test Accuracy Proportion, $r(11) = -.57$, $p = .065$. This finding for the HFA children shows that there might be similar skills required in completing sentence stems and completing a causal sequence using pictures.

Additionally, for the AS group, local processing (i.e., Children's Embedded Figures Test Accuracy Proportion, Correct Response Time and Sentence Completion Test) were not correlated with Systemizing Quotient –Child Version scores, $r_s(11) < .42$, $p_s > .203$, or the Picture Sequencing Test Transformed Accuracy Proportion, $r_s(11) < .10$, $p_s > .773$, although there was also a trend for a positive relationship between Children's Embedded Figures Test Accuracy Proportion and Picture Sequencing Test Accuracy Proportion scores, $r(11) = .59$, $p = .058$. This trend might be tapping into similar cognitive processing required to complete visuospatial tasks.

Finally, for the TD group, local processing was not significantly related to systemizing abilities, $r_s(25) < .29$, $p_s > .158$. However, there was a trend for a positive relationship between Children's Embedded Figures Test Accuracy Proportion and the Systemizing Quotient – Child Version Scores, $r(25) = .39$, $p = .055$ and a trend for a positive relationship between the Sentence Completion Task Overall Score and the

Picture Sequencing Test Accuracy Proportion, $r(24) = .39, p = .060$. This suggests that visuospatial and linguistic local processing may relate differently to parent-reported systemizing interests/behaviors and performance on sequencing causal relationships for TD children.

Evaluation of Systemizing as a Predictor of Language Abilities

It was hypothesized that children with ASD may exhibit language difficulties due to an overreliance on rules or a drive to systemize. Due to these differences in language abilities previously determined between the HFA and AS groups, they were analyzed separately as there could be underlying differences in cognitive processes between the HFA and AS groups related to language ability. By evaluating these groups separately, it was expected that any differences in language ability associated with a drive to systemize could be teased apart more effectively. Mean Core Language scores for the HFA, AS, and TD groups are shown in Figure 1.

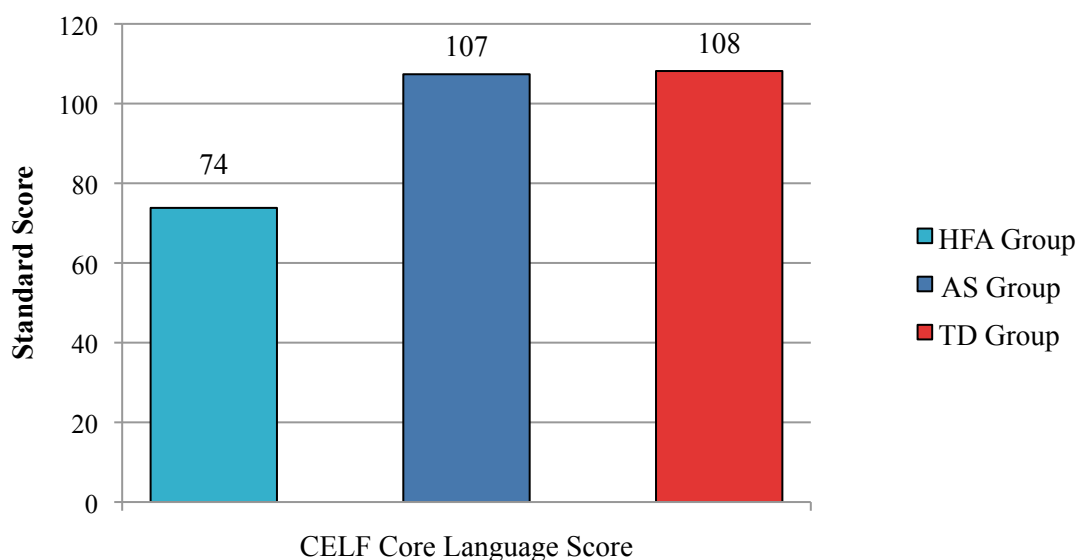


Figure 1. Mean Core Language Scores for the Clinical Evaluation of Language Fundamentals – 4th version across the HFA, AS, and TD Groups.

Tests of normality found that the Systemizing Quotient-Child Version raw scores and the Core Language Scores met assumptions of normality and heterogeneity of variance. As these tests also found that the Picture Sequencing Test Accuracy proportion scores were negatively skewed for the HFA group, an arcsine transformation was conducted on these scores. The transformed Picture Sequencing Test Accuracy proportion scores were then used in the following analyses.

Table 4. Regression Coefficients for Systemizing Ability Measures as Predictors of Children's Core Language Ability

Group	<i>B</i>	<i>S.E. B</i>	β	<i>t</i>	Sig.
HFA					
PST Accuracy	35.00	21.02	.49	1.67	.13
SQ-C	0.73	0.77	.28	0.95	.37
AS					
PST Accuracy	-7.45	27.21	-.11	-0.27	.79
SQ-C	0.54	0.66	.32	0.82	.43
TD					
PST Accuracy	-4.84	11.00	-.09	-0.44	.67
SQ-C	0.25	0.23	.23	1.07	.30

Notes: PST Accuracy – Picture Sequencing Test Transformed Accuracy Proportion
 SQ-C – Systemizing Quotient – Child Version

To determine if systemizing ability would be a reliable predictor of language abilities in children with ASD, separate linear regression analyses were conducted for each group (i.e., HFA, AS, and TD). Results from the linear regression for the HFA, AS, and TD groups is presented in Table 4. The linear regression analyses found that systemizing ability as determined by Picture Sequencing Test Accuracy Proportion and

Systemizing Quotient-Child Version scores were not significant predictors of language ability in the HFA group, $R^2 = .42$, $F(2, 8) = 2.90$, $p = .113$, in the AS group, $R^2 = .08$, $F(2, 8) = 0.35$, $p = .717$, or in the TD group, $R^2 = .06$, $F(2, 21) = 0.62$, $p = .547$.

Relationship between systemizing abilities (PST, SQ-C) and core language subtests. To further explore how a drive to systemize may be related to specific aspects of language, Pearson correlation analyses were conducted on the Picture Sequencing Test-Accuracy, Systemizing Quotient - Child and the subtests of the CELF-4 (i.e., Concepts and Following Directions, Word Structure, Recalling Sentences, Formulated Sentences, and Word Classes) separately for the HFA, AS, and TD groups. Group means for the Clinical Evaluation of Language Fundamentals – 4th Version subtests are presented in Table 5.

Table 5. Group Means and Standard Deviations for CELF-4 Subtest Scaled Scores for HFA, AS, and TD Groups

CELF-4 Subtest	HFA ($n = 11$)		AS ($n = 11$)		TD ($n = 24$)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Concepts & Following Directions	6.55	3.91	10.18	2.79	10.38	2.55
Word Structure ^a	5.00	^c	6.50	3.54	9.33	3.31
Recalling Sentences	5.36	4.11	11.09	3.42	12.08	2.32
Formulated Sentences	4.36	3.04	11.18	2.60	11.17	2.50
Word Classes – Total ^b	7.70	3.20	13.89	2.26	13.75	3.08

Note: Scaled scores are based on a mean of 10 and standard deviation of 3.

^a – Word Structure subtest only administered to children age 7 through 8

^b – Word Classes – Total subtest only administered to children age 9 through 11

^c – Standard deviation was not calculated due to $n = 1$

Table 6. Pearson Correlations for CELF-4 Subtests and Systemizing Ability Measures Across HFA, AS, and TD Groups

Group	CnFD	WS	RS	FS	WC-T
<u>HFA</u>					
PST Accuracy	.348	^a	.523	.357	.693*
SQ-C	.568	^a	.359	.326	.448
<u>AS</u>					
PST Accuracy	-.180	^a	-.206	.150	.304
SQ-C	.176	^a	.013	.413	.218
<u>TD</u>					
PST Accuracy	-.239	-.159	-.171	.079	.293
SQ-C	.221	.340	.083	.211	.032

Note: CnFD – Concepts & Following Directions; WS – Word Structure; RS – Recalling Sentences; FS – Formulated Sentences; WC-T – Word Classes Total

^a – correlations were not run due to small sample size.

* - $p < .05$

In the HFA group, Pearson correlation analyses found that Picture Sequencing Test Accuracy scores were positively related to the Word Classes – Total subtest, $r(10) = .69, p = .026$. This indicates that accuracy in ordering causal relationships was positively related to HFA children's ability to detect and describe logical relationships between words. In the AS group, there were no significant relationships between the Core Language subtests and the systemizing ability measures, $rs(9) < .41, ps > .207$. This pattern was also found for the TD group, $rs(12) < .38, ps > .221$. The results of the correlation analyses are shown in Table 6. These results indicate that there may some link between systemizing abilities and language in HFA children, particularly in how

they approach logical problems. In contrast, AS and TD children may be utilizing different cognitive resources in understanding logical problems.

Comparing Global/Context and Rule Based Processing in a Counterfactual Reasoning Task

An additional aim of the present study was to explore how children with ASD processed information that could be interpreted based on established previous knowledge/rules or new contextual information. To explore biases in the interpretation of counterfactual information, children's responses and explanations on the Counterfactual Reasoning Task were calculated as proportions across a real world and imaginary world condition. Separate proportions were calculated for contextual and rule-based responses and for contextual and rule-based explanations. For example, item 3 from the real world condition reads, "All fish live in trees. Tot is a fish. Does Tot live in a tree?" A context response to this item would consist of a "Yes" answer because it is based on the current information presented, not previous knowledge or rules of nature. A response of "No" would be considered a rule-based response as it reflects a reliance on previous knowledge or rules of nature in that fish do not live outside bodies of water. Responses and explanations that were arbitrary, incoherent or irrelevant were not included in the proportions. It was expected that children with HFA and AS would provide more rule-based responses and explanations, whereas TD children were expected to utilize the provided context, therefore would have higher contextual scores for responses and explanations.

Initial analyses evaluated children's responses to the control questions to ensure that previous knowledge of the main concepts were similar between groups. Due to the linguistic content of the Counterfactual Reasoning Task, analyses were conducted separately for the HFA, AS and TD children. The mean proportion of control questions answered correctly was .83 for the HFA group, .90 for the AS group, and .93 for the TD group. A One-way ANOVA found no significant differences in the proportion of control questions passed between the HFA, AS, and TD groups, $F(2, 44) = 2.87, p = .067$. This provided support that children's existing knowledge did not differ between the groups and any differences in response to the CRT statements could be attributed to individual biases.

Preliminary analyses showed that the scores for the Counterfactual Reasoning Task violated assumptions of normality and homogeneity of variance. Arcsine transformations did not provide an advantage, therefore, raw scores for the Counterfactual Reasoning Task were kept and non-parametric tests were used to analyze children's responses across groups. Overall, there were significant differences in the proportion of context responses between groups on the real world condition, $H(2) = 11.19, p = .004$, and the imaginary world condition, $H(2) = 9.25, p = .008$. Mann-Whitney tests were used to follow up this significant result and a Bonferroni correction for multiple comparisons was used. There was a significant difference in the proportion of context responses between the HFA and AS groups for the real world condition, ($U = 24.00, p = .013, r = -2.45$), but not the imaginary world condition, ($U = 34.00, p = .075, r = -1.81$).

Additionally, there was a significant difference in the proportion of context responses between the HFA and TD groups, for the real world condition, ($U= 46.50, p = .001, r = -3.24$), and imaginary world condition, ($U= 57.50, p = .002, r = -3.03$). Finally, comparisons between the AS and TD groups showed no difference in the proportion of context responses for the real world condition, ($U= 137.00, p = .992, r = -.02$), or the imaginary world condition, ($U= 118.00, p = .451, r = -.79$). Mean proportion of context responses for each condition by group are displayed in Figure 2.

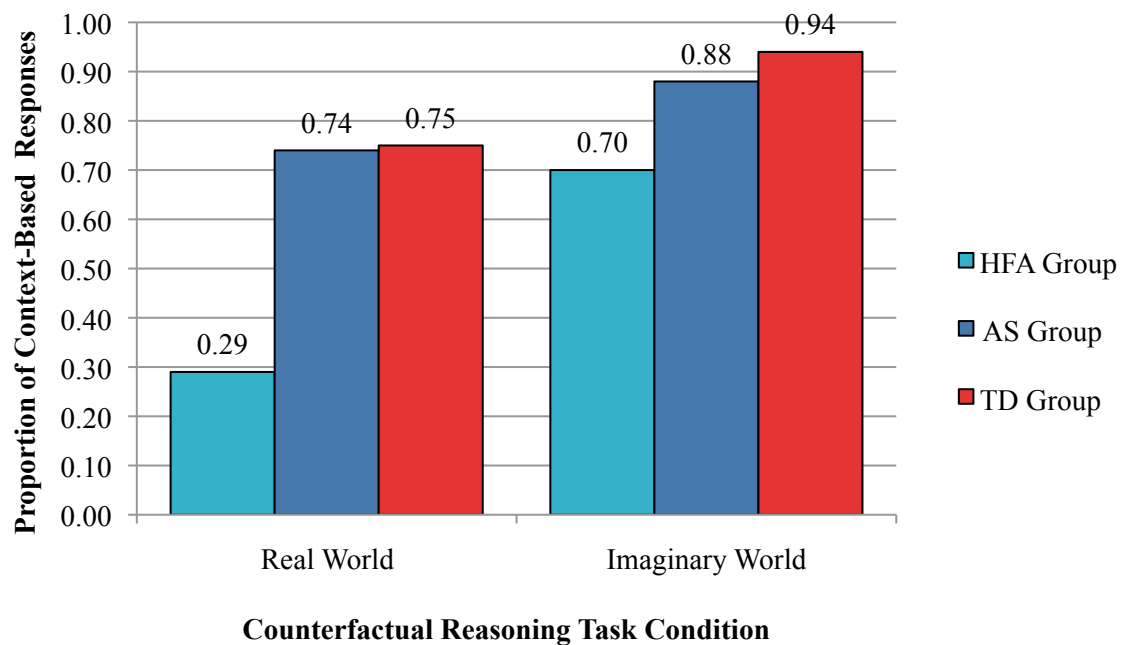


Figure 2. Mean proportions for context-based responses to the Real World and Imaginary World Conditions for the CRT task across HFA, AS, and TD Groups.

To determine if there were differences in context responses within participants between the Real World and Imaginary World conditions, Wilcoxon Signed Ranks tests were conducted separately for each group. These analyses found in the HFA group that there was a significant difference in context responses between the Real World ($Mdn =$

.13) and Imaginary World conditions ($Mdn = .50$), $z = -2.2$, $p = .029$, $r = -.47$.

Additionally, in the AS group there were no significant difference between context responses across the Real World ($Mdn = 1.00$) and Imaginary World conditions ($Mdn = 1.00$), $z = -1.38$, $p = .25$, $r = -.29$. Finally, the TD group provided a greater proportion of context responses for the Imaginary World ($Mdn = 1.00$) than the Real World condition ($Mdn = 1.00$), $z = -2.37$, $p = .015$, $r = -.34$. These analyses indicate that when previous knowledge is eliminated from the task, children in the HFA and TD groups are more likely to utilize the context provided to interpret counterfactual statements, whereas the AS group is just as likely to utilize context when provided with conflicting and new information.

A final analysis was conducted to determine if there were significant differences in the response biases across groups. Children's context and rule-based response proportions to the real world condition were used to determine their cognitive bias. Proportions greater than or equal to .875 (i.e., 7 out of 8 items) were assigned a bias for the respective response type (i.e., context-based vs. rule-based). This strict proportion score was used to parallel that of previous research (Leavers & Harris, 2000). If the proportions for either context or rule-based responses were less than .875, the child was categorized as Mixed Bias.

There was no significant difference in cognitive bias for the HFA, $\chi^2(2, N = 11) = 2.36$, $p = .413$, and AS groups, $\chi^2(2, N = 11) = 5.09$, $p = .098$. However, the TD group demonstrated a greater bias towards context-based responses than rule-based responses, $\chi^2(2, N = 25) = 12.08$, $p = .002$. Although the analyses for the HFA and AS groups were

non-significant, this may be due to the small sample size for each group as some cells had expected values less than 5. These two groups were not collapsed together as observations of their bias distribution showed a trend towards more similar performance between the AS and TD groups than between the HFA and AS groups. Figure 3 shows the percentage of children classified as having a context, rule, or mixed bias across the HFA, AS, and TD groups.

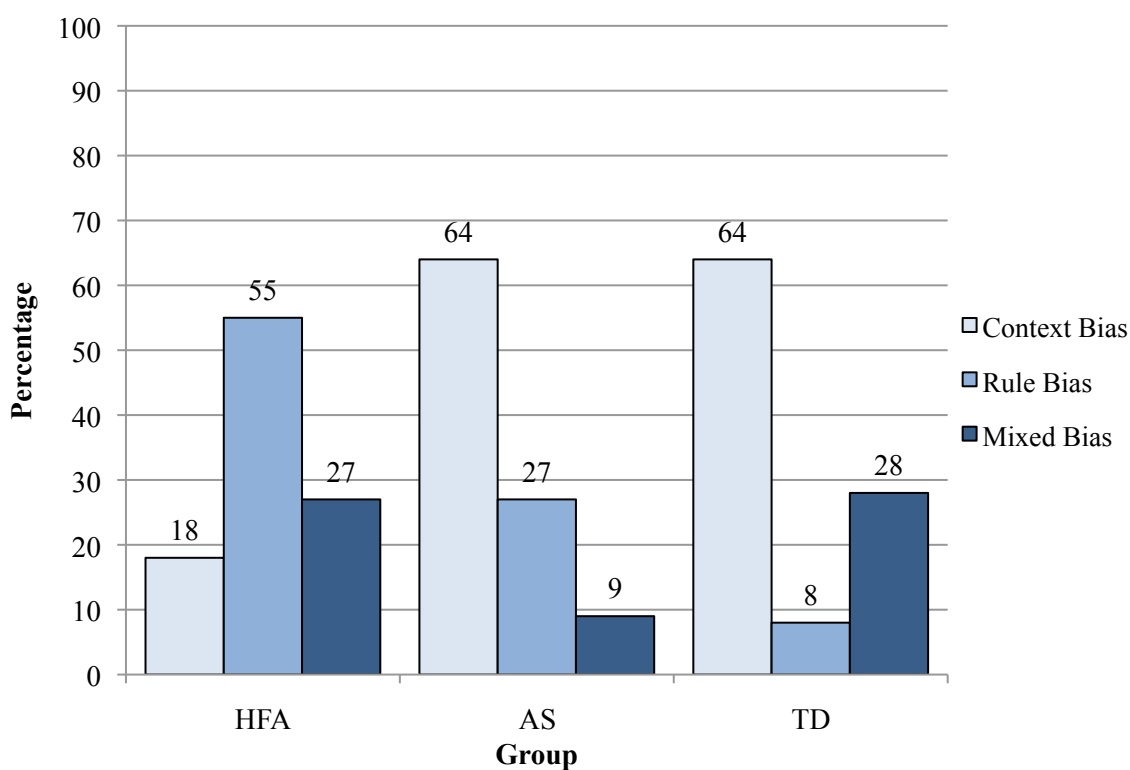


Figure 3. Percentage of children classified as Context, Rule, or Mixed Bias for the Counterfactual Reasoning Task Real World Condition Across HFA, AS, and TD Groups.

The results on the Counterfactual Reasoning Task demonstrate that children with HFA exhibit a greater reliance on their previously established knowledge/rules rather than consider new contextual information. However, when presented with brand new

information that did not conflict previous knowledge/rules, children with HFA were more apt to use contextual information. On the other hand, children with AS and TD children, accepted new contextual information more readily across conditions that contradicted their previous knowledge and conditions with no conflicts.

Assessing the Relationship Between Overall Parent-Reported Autism Behaviors, Local Processing and Systemizing Abilities

It was expected that parent-reported autism behaviors would be strongly related to children's cognitive biases, such that children with higher reported autism traits would also have higher scores on local and rule-based processing measures. To investigate these potential relationships, Pearson correlation analyses were conducted on the total score of the Autism Spectrum Quotient – Child Version (ASQ-C) and scores for local processing (i.e., Children's Embedded Figures Test Correct Trials, Children's Embedded Figures Test Average Response Time, Sentence Completion Task Overall Score) and systemizing abilities (i.e., Systemizing Quotient - Child, arcsine transformed Picture Sequencing Test Proportion Correct). Mean scores for the ASQ-C are presented in Table 7 for the HFA, AS, and TD groups.

Table 7. Mean Scores for the Autism Spectrum Quotient Domains Across the HFA, AS, and TD Groups

ASQ Domain	HFA ($n = 11$)		AS ($n = 11$)		TD ($n = 24$)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Social Skills	17.09	6.06	17.73	5.52	6.64	3.39
Attn. Switching	21.00	5.35	21.91	4.72	10.40	4.44
Attn. to Detail	17.00	5.97	20.64	4.03	14.24	5.72
Communication	22.64	4.74	21.73	3.64	8.00	4.73
Imagination	17.82	5.74	17.09	4.13	7.28	3.73
ASQ Total	95.55	18.36	99.09	14.10	46.56	14.29

Note: Attn – Attention; Domain scores have a maximum value of 30. ASQ Total cutoff score is 72 for ASD diagnosis. No TD children had scores > 68.

Pearson correlation analyses found for the HFA group that the overall ASQ-C score was not significantly correlated with local processing, $rs(11) < .42, ps > .195$, or systemizing abilities, $rs(11) < .15, ps > .663$. This means that parent-reported autism traits were not related to HFA children's local processing in the visual and linguistic domains and not related to their ability to sequence causal relationships or parent-reported systematic interests and activities. Analyses with the AS group found that the overall ASQ-C score was not significantly correlated with local processing, $rs(11) < .11, ps > .75$, or systemizing abilities, $rs(11) < .12, ps > .733$. This means that parent-reported autism traits were not related to AS children's local processing, their ability to sequence causal relationships or rule-based interests and activities.

For the TD group, Pearson correlation analyses found that the overall ASQ-C score was not significantly correlated with local processing, $r_s(24) < .09, p_s > .234$, or systemizing abilities, $r_s(24) < .36, p_s > .079$. This means that similarly to the HFA and AS groups, parent-reported autism traits were not related to TD children's local processing in the visual and linguistic domains and they were not related to TD children's ability to sequence causal relationships or parent-reported systematic interests and activities.

Assessing the relationship between autism domains, local processing (CEFT, SCT) and systemizing abilities (PST, SQ-C). Additional correlational analyses were conducted to evaluate the relationship between domains (i.e., Social skills, Attention switching, Attention to Detail, Communication and Imagination) underlying the total ASQ-C score and cognitive biases. Table 7 presents the mean scores for the ASQ-C domains for the HFA, AS, and TD groups. These analyses found in the HFA group, a significant positive relationship between Children's Embedded Figures Test Response Time and the ASQ – Social Skills domain, $r(11) = .68, p = .022$. The ASQ – Communication domain was also positively related to Children's Embedded Figures Test Accuracy, $r(11) = .67, p = .025$. Thus, longer response times in correctly disembedding hidden figures were positively related to higher levels of difficulties in social skills, whereas the proportion of correctly disembedded figures was related to greater difficulties in communication skills in the HFA group.

Analyses conducted with the AS group found a significant negative relationship between the ASQ – Attention Switching domain and Sentence Completion Task Overall

Scores, $r(11) = -.68, p = .023$. Furthermore, there was also a significant negative relationship between the ASQ – Imagination domain and the Systemizing Quotient - Child scores, $r(11) = -.61, p = .048$. Thus, in the AS group, higher levels of local processing of linguistic information was related to less difficulties in shifting attention. In addition, higher levels of systematic interests and behaviors were related to fewer difficulties in imaginative play.

For the TD group, Pearson correlation analyses found that Children's Embedded Figures Test Correct Trials were negatively related to ASQ-Social Skills domain and, $r(25) = -.41, p = .043$, and positively related to the ASQ – Attention to Detail subscale, $r(25) = .44, p = .028$. TD children's response time for correct trials on the Children's Embedded Figures Test were also negatively related to ASQ-Communication domain, $r(24) = -.43, p = .038$. There was also a negative relationship between Systemizing Quotient - Child scores and the ASQ-Social Skills domain, $r(25) = -.41, p = .042$ and a positive relationship between the Systemizing Quotient - Child scores and the ASQ – Attention to Detail subtest, $rs(25) = .84, p < .001$. This means that as the number of embedded figures correctly located increased for TD children, their parent-reported level of social skills difficulties decreased and their parent-reported level of attention to detail increased. In addition, higher levels of parent-reported systematic interests and activities in the home were related to lower levels of social skills difficulties and higher levels of parent-reported attention to details in the home.

Overall, it appears that attention to detail in HFA and TD children may be transferring to systemizing preferences in the home. In contrast, AS children's attention

switching and imaginative play may foster greater flexibility in local processing and systemizing preferences in the home.

Measuring the Relationship Between Executive Functioning, Local Processing and Systemizing Abilities

It was expected that children's executive functioning (EF) might be related to local processing and systemizing. To date, no studies have thoroughly evaluated possible relationships between local processing, systemizing, and executive functioning. The following analyses were exploratory in nature to determine if EF contributes to performance on local processing and systemizing tasks in HFA, AS, and TD children. Mean T scores (i.e., standard mean = 50, standard deviation = 10) for parent-reported executive dysfunction (BRIEF-GEC) and children's EF performance (WCST-PE) can be found in Figure 4 for the HFA, AS, and TD groups.

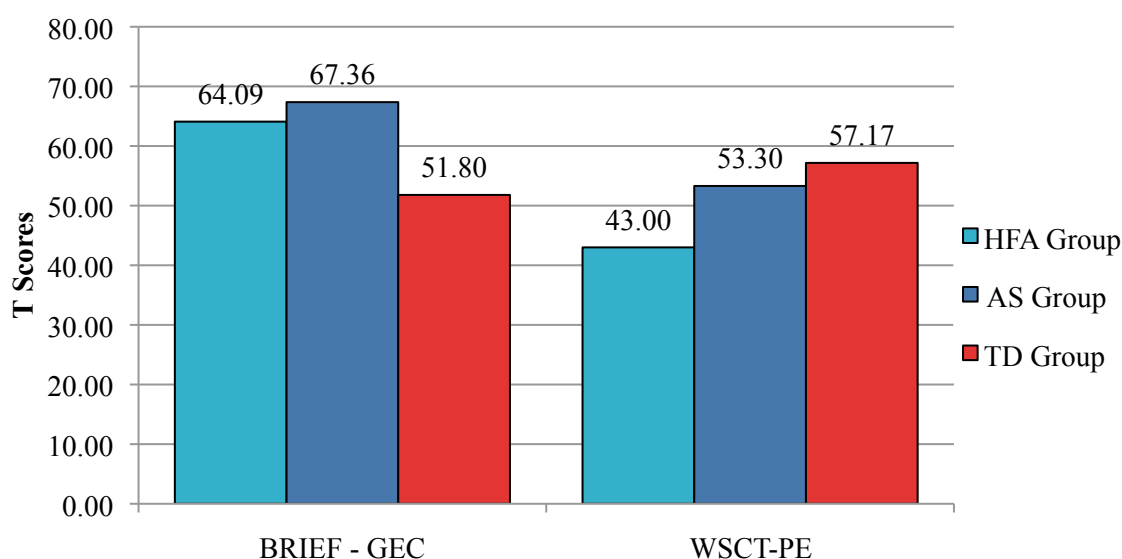


Figure 4. Mean T scores for the BRIEF and the WCST-64 for HFA, AS, and TD Groups.
Note: Higher T scores for the BRIEF-GEC scale represent greater dysfunction; Higher T scores for the WCST represent lower perseverative errors.

Pearson correlation analyses were conducted with the BRIEF-Global Executive Composite T scores, WCST-Perseverative Error T Scores, and the local processing (i.e., Children's Embedded Figures Test Correct Trials, Children's Embedded Figures Test Average Response Time, Sentence Completion Task Overall Score) and systemizing abilities (i.e., Systemizing Quotient - Child, arcsine transformed Picture Sequencing Test Proportion Correct). As past studies have found age-related improvements in EF (e.g., Huizinga & Smidts, 2011; Luciana, 2003; O'Hearn, Asato, Ordaz, & Luna, 2008), partial correlations controlling for chronological age were then run to determine if the relationship between EF and the Local Processing and Systemizing variables remained after accounting for developmental effects. The correlation analyses with the HFA group found that the BRIEF-Global Executive Composite T Score, $r_{s(11)} < .47, p > .117$, and the WCST-Perseverative Errors T Scores, $r_{s(11)} < .24, p > .299$, were not related to any local processing or systemizing variables. Partial correlations controlling for age maintained the non-significance of these findings (see Table 8).

Table 8. Pearson Correlations for BRIEF-GEC and WCST-PE Scores Across Local Processing and Systemizing Variables for HFA, AS, and TD Groups

Group	BRIEF – GEC		WCST-PE	
HFA	<i>r</i>	partial <i>r</i> ^a	<i>r</i>	partial <i>r</i> ^a
CEFT Accuracy	.469	.493	-.345	-.304
CEFT Response Time	.381	.379	.236	.232
SCT Overall	-.134	-.243	.150	-.062
PST Accuracy	-.265	-.260	.109	.198
SQ-C	-.500	-.503	-.115	-.050
AS				
CEFT Accuracy	.488	.511	.613	.610
CEFT Response Time	.770**	.931***	.213	.203
SCT Overall	-.762**	-.722*	-.117	-.084
PST Accuracy	.084	-.024	.761*	.767*
SQ-C	.146	.632	.278	.298
TD				
CEFT Accuracy	-.402*	-.493*	.536**	.490*
CEFT Response Time	-.147	-.198	-.110	-.216
SCT Overall	.040	.063	.278	.366
PST Accuracy	.437*	.418	.035	-.066
SQ-C	-.302	-.294	.230	.305

Note: BRIEF-GEC – Behavior Rating Inventory of Executive Function – Global Executive Composite; WCST-PE – Wisconsin Card Sorting Task Perseverative Errors

^a - Partial correlations controlling for chronological age

* - $p < .05$, ** - $p < .01$, *** - $p < .001$

The analyses for the AS group found that the BRIEF-Global Executive Composite T Score was positively related to Children's Embedded Figures Test Response Time, $r(11) = .77, p = .006$. Thus, children with AS who exhibited greater executive dysfunction took longer to correctly locate embedded figures. Analyses with the AS group also revealed a negative relationship between BRIEF – Global Executive Composite and Sentence Completion Task Overall Score, $r(11) = -.76, p = .006$. Children with AS who had higher levels of executive dysfunction also provided more locally coherent responses to a linguistic processing task. Additionally, a positive relationship was also found between WCST-Perseverative Errors and Picture Sequencing Test Accuracy, $r(11) = .76, p = .011$. Children with AS who engaged in more age appropriate perseveration were more accurate in sequencing causal relationships. These relationships between EF and local processing and systemizing remained significant even after controlling for chronological age (see Table 8).

Finally, correlation analyses for the TD group showed that the BRIEF – Global Executive Composite was negatively related to the Children's Embedded Figures Test Accuracy, $r(25) = -.40, p = .046$. Thus, TD children who had lower levels of parent-reported executive dysfunction were more accurate in locating an embedded figure. Further correlation analyses found that the BRIEF – Global Executive Composite was positively related to the Picture Sequencing Test Accuracy, $r(24) = .44, p = .033$. In this case, children with higher levels of parent-reported executive dysfunction were more accurate in sequencing causal relationships using pictures. Evaluation of the correlation analyses with the WCST-Perseverative Errors in TD children finds a positive relationship

with the Children's Embedded Figures Test Accuracy, $r(24) = .54, p = .007$. Children who had exhibited more age-appropriate perseveration on the card-sorting task were more accurate in locating embedded figures. Partial correlations controlling for chronological age found that only the relationships of the Children's Embedded Figures Test Accuracy with the BRIEF – Global Executive Composite and with the WCST-Perseverative Errors remained significant, $rs(20) < .49, ps < .021$.

Analyzing the relationship between BRIEF subscales, local processing (CEFT, SCT), and systemizing abilities (PST, SQ-C). Further analyses were conducted to determine if specific subscales from the BRIEF parent questionnaire would be related to local processing and systemizing variables. Means for the BRIEF subscales for the HFA, AS and TD groups are presented in Table 9. These analyses might shed light on specific aspects of EF would map onto cognitive biases that might not have been revealed with the Global Executive Composite score.

The Pearson correlation analyses in the HFA group found that the BRIEF-Inhibit subscale was negatively related to the Picture Sequencing Test Accuracy, $r(11) = -.62, p = .043$ (partial correlation controlling for chronological age, $r(8) = -.63, p = .052$). The BRIEF-Initiate subscale was positively related to the Children's Embedded Figures Test Response Time for Correct Trials, $r(11) = .76, p = .007$ (partial correlation controlling for chronological age, $r(8) = .76, p = .011$). Other BRIEF subtests (Shift, Emotional Control, Working Memory, Plan and Organize, Organization of Materials, and Monitor) were not significantly related to the local processing variables in the HFA group, $rs(11) < .53, ps > .092$, or the systemizing variables, $rs(11) < .10, ps > .068$, see Table 10. These additional

analyses show that children with HFA who exhibit greater difficulties inhibiting behavior were less accurate in sequencing causal relationships; children with HFA who had greater challenges initiating new tasks also took longer to accurately locate embedded figures. Thus, for children with HFA, it appears that deficits in executive functioning transfer to tasks that focus on local processing and systemizing.

In the AS group, the BRIEF-Shift subscale was positively related to the Children's Embedded Figures Test Response Time for Correct Trials, $r(11) = .62, p = .043$ (partial correlation controlling for chronological age, $r(7) = .56, p = .118$) and negatively related to the Sentence Completion Task Overall Score, $r(11) = -.64, p = .036$ (partial correlation controlling for chronological age, $r(7) = -.56, p = .114$). The BRIEF-Initiate, Working Memory, and Plan/Organize subscales were also positively related to the Children's Embedded Figures Test Response Time for Correct Trials, $r(11) > .64, p < .035$ (partial correlation controlling for chronological age only remained significant for Working Memory subscale, $r(7) = .80, p = .009$). The BRIEF-Plan/Organize subscale was also negatively related to the Sentence Completion Task Overall Score in AS children, $r(11) = -.67, p = .024$ (partial correlation controlling for chronological age, $r(7) = -.59, p = .097$).

The BRIEF-Inhibit, Emotional Control, Organization of Materials, and Monitor subscales were not significantly related to the local processing variables, $r(11) < .54, ps > .071$, or the systemizing variables in the AS group, $r(11) < .39, ps > .231$, see Table 10. These overall results for the BRIEF subscales in children with AS demonstrate that many executive processes may be involved in the response speed of visuospatial local

processing. Greater difficulties in cognitive shifting, initiating tasks, working memory, and planning and organizing contributed to an increase in the amount of time required to accurately locate a hidden figure. Furthermore, it was also shown that deficits in cognitive shifting and planning and organization were also related to lower scores on a linguistic local processing task for AS children. This indicates that EF deficits may in fact contribute to less of a local bias on visuospatial and linguistic tasks in children with AS.

Table 9. Group Means for the BRIEF Subscales for the HFA, AS, and TD Groups

BRIEF Subscales ^a	HFA (<i>n</i> = 11)		AS (<i>n</i> = 11)		TD (<i>n</i> = 25)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Inhibit	61.27	8.96	65.45	9.52	51.28	11.52
Shift	70.09	14.44	68.36	10.42	51.08	8.28
Emotional Control	59.09	11.25	63.09	10.35	50.40	8.32
Initiate	60.82	10.00	62.82	11.19	51.72	11.56
Working Memory	60.73	11.47	62.82	13.39	52.00	9.94
Plan and Organize	60.91	12.86	60.55	8.23	50.72	10.42
Organization of Materials	55.09	12.00	62.36	8.20	54.12	10.16
Monitor	64.45	8.94	65.73	7.39	50.72	11.91

Note: ^a – Subscale T Scores have a mean of 50 and standard deviation of 10. Scores above 65 are considered in the clinical threshold of executive dysfunction

Finally, correlation analyses for the TD group found that the BRIEF-Initiate subscale was negatively related to the Children's Embedded Figures Test Accuracy proportion, $r(25) = -.45, p = .023$ (partial correlation controlling for chronological age,

$r(20) = -.49, p = .021$). Inspection of the BRIEF-Inhibit, Emotional Control, and Initiate subscales showed a positive relationship with the Picture Sequencing Test accuracy, $rs(24) > .41, ps < .04$ (partial correlations controlling for chronological age only remained significant for the Inhibit subscale, $r(20) = .43, p = .045$). The remaining BRIEF subscales (i.e., Shift, Working Memory, Plan/Organize, Organization of Materials, and Monitor) were not significantly related to the local processing, $rs(24) < .27, ps > .055$, and the systemizing variables, $rs(24) < .39, ps > .054$, see Table 10. These results for the TD children illustrate that difficulties with task initiation contributed to lower accuracy on detecting a hidden figure, whereas greater challenges in inhibition, emotional control, and initiating tasks resulted in higher accuracy in sequencing causal relationships using pictures.

These overall results indicate that EF may function in distinct ways in children's local processing and systemizing for the HFA, AS and TD groups. It seems that EF is related to visuospatial and linguistic local processing tasks in AS children whereas, HFA children may only tap into their inhibitory and initiation skills when completing visuospatial local processing tasks. Overall EF and cognitive flexibility appear to influence TD children's performance on visuospatial tasks that require both local processing and systemizing.

Table 10. Pearson Correlations Across BRIEF Subscales and Cognitive Bias Measures For HFA, AS, and TD Groups

Group	IH	SH	EC	IN	WM	PO	OM	MO
<u>HFA</u>								
CEFT Acc.	.206	.502	.532	.498	.403	.442	.073	.452
CEFT RT	-.049	.287	.393	.759**	.326	.424	.115	.175
SCT Overall	-.705*	-.301	-.106	-.134	-.150	-.207	.135	-.072
PST Acc.	.273	-.053	-.157	.099	-.376	-.197	.023	-.329
SQ-C	.250	-.384	-.444	-.314	-.287	-.433	-.568	-.403
<u>AS</u>								
CEFT Acc.	.478	.320	.155	.366	.457	.273	.470	.474
CEFT RT	.456	.617*	.535	.637*	.692*	.679*	.334	.261
SCT Overall	-.367	-.636*	-.564	-.586	-.527	-.669	-.535	-.584
PST Acc.	.295	.357	.319	-.193	-.106	-.254	.236	.096
SQ-C	.394	.307	.371	-.060	.021	-.172	.036	.042
<u>TD</u>								
CEFT Acc.	-.258	-.191	-.296	-.454	-.389	-.361	-.283	-.366
CEFT RT	-.107	-.058	-.289	-.227	-.055	-.011	-.178	-.082
SCT Overall	-.052	.128	.271	.048	-.008	-.011	-.164	.105
PST Acc.	.410*	.342	.418*	.422*	.351	.376	.179	.391
SQ-C	-.298	.070	-.113	-.328	-.391	-.301	-.172	-.272

Note: IH – Inhibit, SH – Shift, EC – Emotional Control, IN – Initiate, WM – Working Memory, PO – Plan and Organize, OM – Organization of Materials, MO – Monitor
 CEFT Acc. – Children’s Embedded Figures Test Accuracy Proportion (out of 25); CEFT RT – Children’s Embedded Figures Test Response Time for Correct Trials in seconds; SCT Overall – Sentence Completion Test Overall Local Processing Score; PST Acc. – Picture Sequencing Test Transformed Accuracy Proportion Score; SQ-C – Systemizing Quotient – Child version Raw Score
 * - $p < .05$, ** - $p < .01$

Utilizing the Developmental Trajectory Approach to Evaluate the Developmental Nature of Cognitive Biases

To evaluate whether there is a developmental relationship between local and rule-based processing, the Developmental Trajectory Approach was used (Thomas, et al., 2009; Thomas, Purser, Van Herwegen, 2011). In this approach, chronological and/or mental age can be used to map the trajectory of performance on tasks of interest. By comparing age-related trajectories across groups, one can determine if cognitive processes are developing in a similar, delayed, or deviant manner across children of different ages.

In order to better detect the developmental trajectories of local processing and systemizing, composite scores were created for each following procedures used by Loth et al. (2008). Raw scores for the Children's Embedded Figures Test Correct Trial Response Time (inverse scores were used so that higher values reflected more proficient local processing), Sentence Completion Task Overall, arcsine transformed Picture Sequencing Test Accuracy, and the Systemizing Quotient-Child Version were transformed into Z-scores and transformed once again so that all variables had a minimum value of 0. The Local Processing Composite was created by summing the transformed z values for the Children's Embedded Figures Test Correct Trial Response Time and Sentence Completion Task Overall Score, with higher scores representing more proficient local processing. The Systemizing Composite was created by summing the transformed z values for the Picture Sequencing Test Accuracy and Systemizing Quotient - Child scores, with higher scores representing a greater drive to systemize. Composite

scores for Local Processing and Systemizing are presented in Figure 5 for the HFA, AS and TD groups.

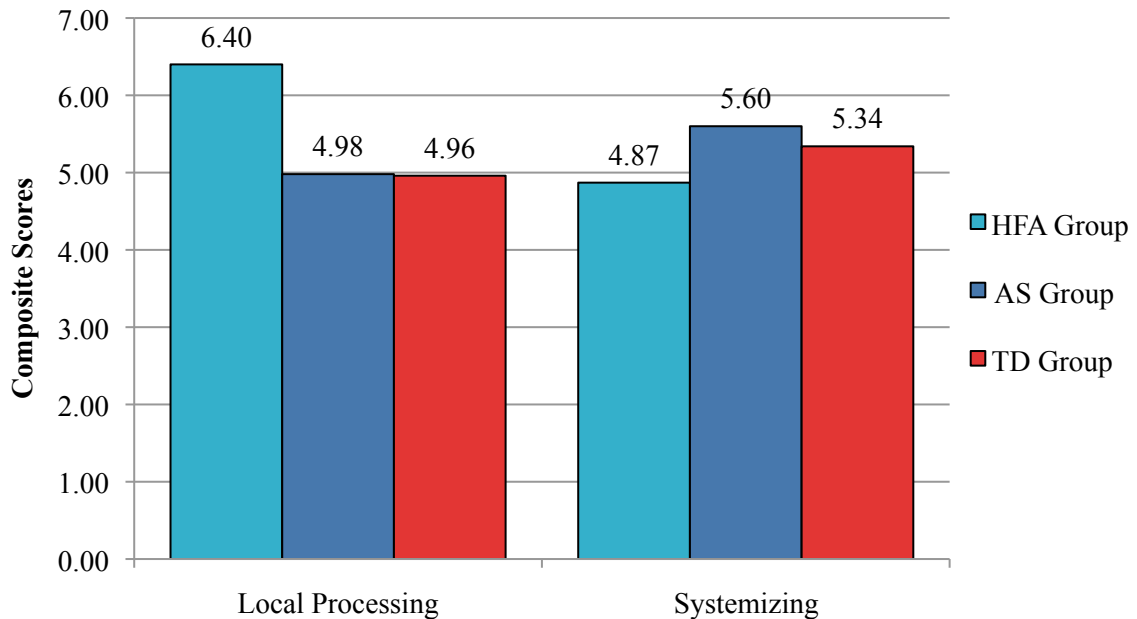


Figure 5. Local processing and systemizing composite scores for the HFA, AS and TD groups.

Verbal mental age trajectories. Following the guidelines outlined by Thomas, et al. (2009), a mixed model ANCOVA with Group as between-subject, Processing Composite as within-subject variable, and verbal mental age (VMA; determined by age equivalency on the CELF-4 subtests) as the covariate was conducted to determine the developmental nature of local and rule-based processing in children with HFA, AS and TD children.

Results from the ANCOVA found a significant main effect of the Processing Composite, $F(1, 40) = 6.17, p = .017$, partial $\eta^2 = .134$ indicating there was a significant difference between the Local Processing and Systemizing Composite scores collapsed across all groups. The Processing Composite X Group Interaction was also significant,

$F(1, 40) = 5.18, p = .01$, partial $\eta^2 = .206$. This shows that there was a significant difference between the HFA, AS, and TD groups across the Local Processing and Systemizing Composite scores.

Additionally, the ANCOVA found a significant Processing Composite X VMA Interaction, $F(1, 40) = 9.93, p = .003$, partial $\eta^2 = .199$, signifying that there was difference in the rate of local processing and systemizing development based on verbal mental age. There was also a significant Processing Composite X Group X VMA Interaction, $F(2, 40) = 3.41, p = .043$, partial $\eta^2 = .146$. This result demonstrates that there was a difference in the developmental relationship between local processing and systemizing abilities across the HFA, AS, and TD groups (see Figure 6 and 7). Inspection of the trajectories indicates that whereas local processing declines, systemizing increases across verbal mental development for the HFA group. The AS group, in contrast, portrays a local processing profile that is not accounted for with a linear function. It appears that local processing for AS children is somewhat random across verbal mental age development. However, within this same group, systemizing increases across verbal mental age, although not at the same rate or onset as HFA children. For TD children, local processing declines at a much slower rate than that of HFA and AS children across verbal mental age. Systemizing in the TD children does not increase or decrease as a function of verbal mental age.

The ANCOVA also found no significant between-subjects effects for Group, $F(2, 40) = .20, p = .824$, partial $\eta^2 = .01$, VMA, $F(1, 40) = .08, p = .777$, partial $\eta^2 = .002$, or the Group X VMA Interaction, $F(2, 40) = .31, p = .734$, partial $\eta^2 = .015$. This indicates

that there were no significant differences in the onset and developmental course of local processing and systemizing and that verbal mental age was not a reliable predictor of performance on local processing and systemizing.

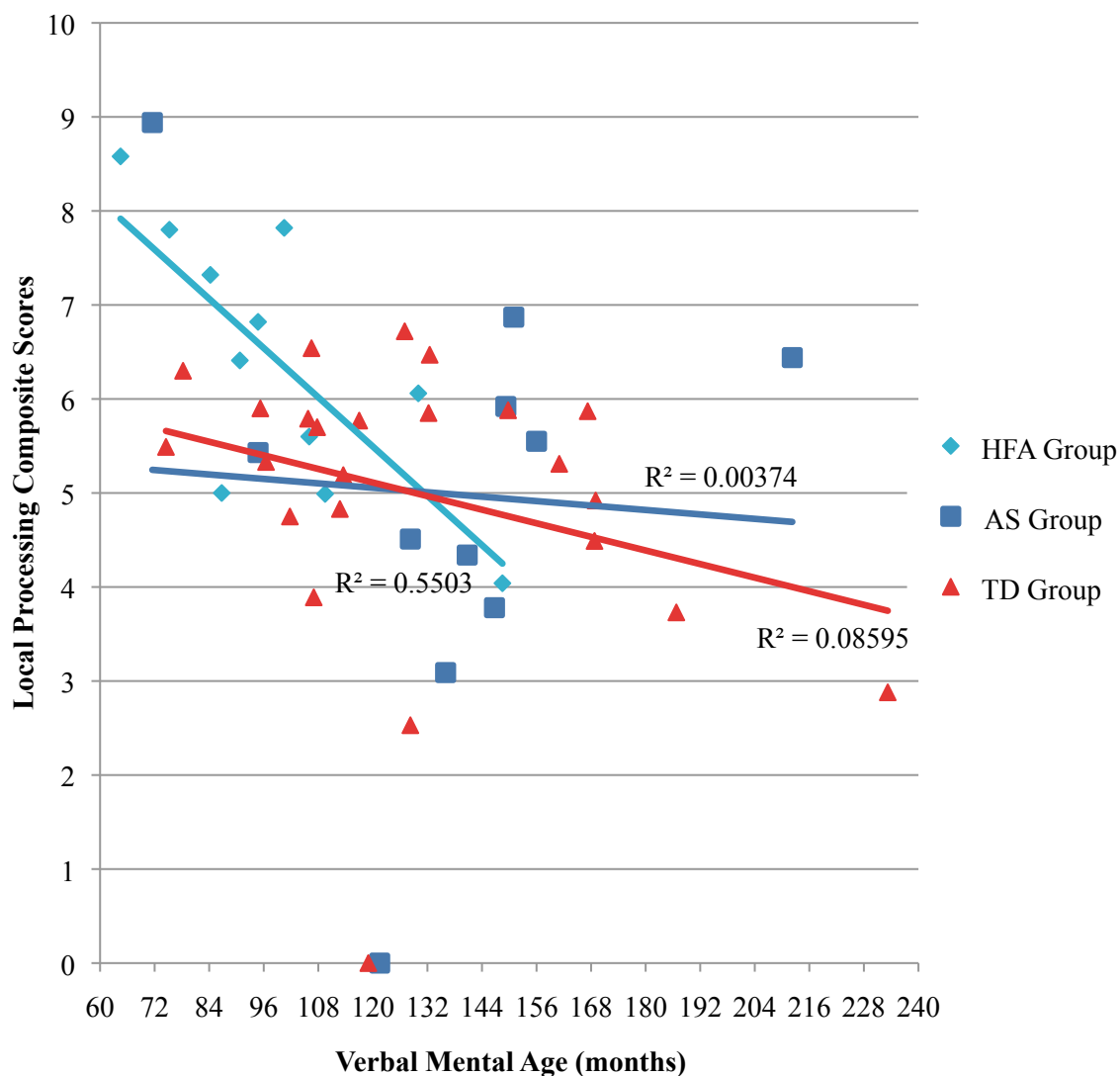


Figure 6. Verbal mental age trajectories of Local Processing Composite Scores for the HFA, AS and TD groups. (Verbal mental age determined by CELF-4 subtests mean age equivalency.)

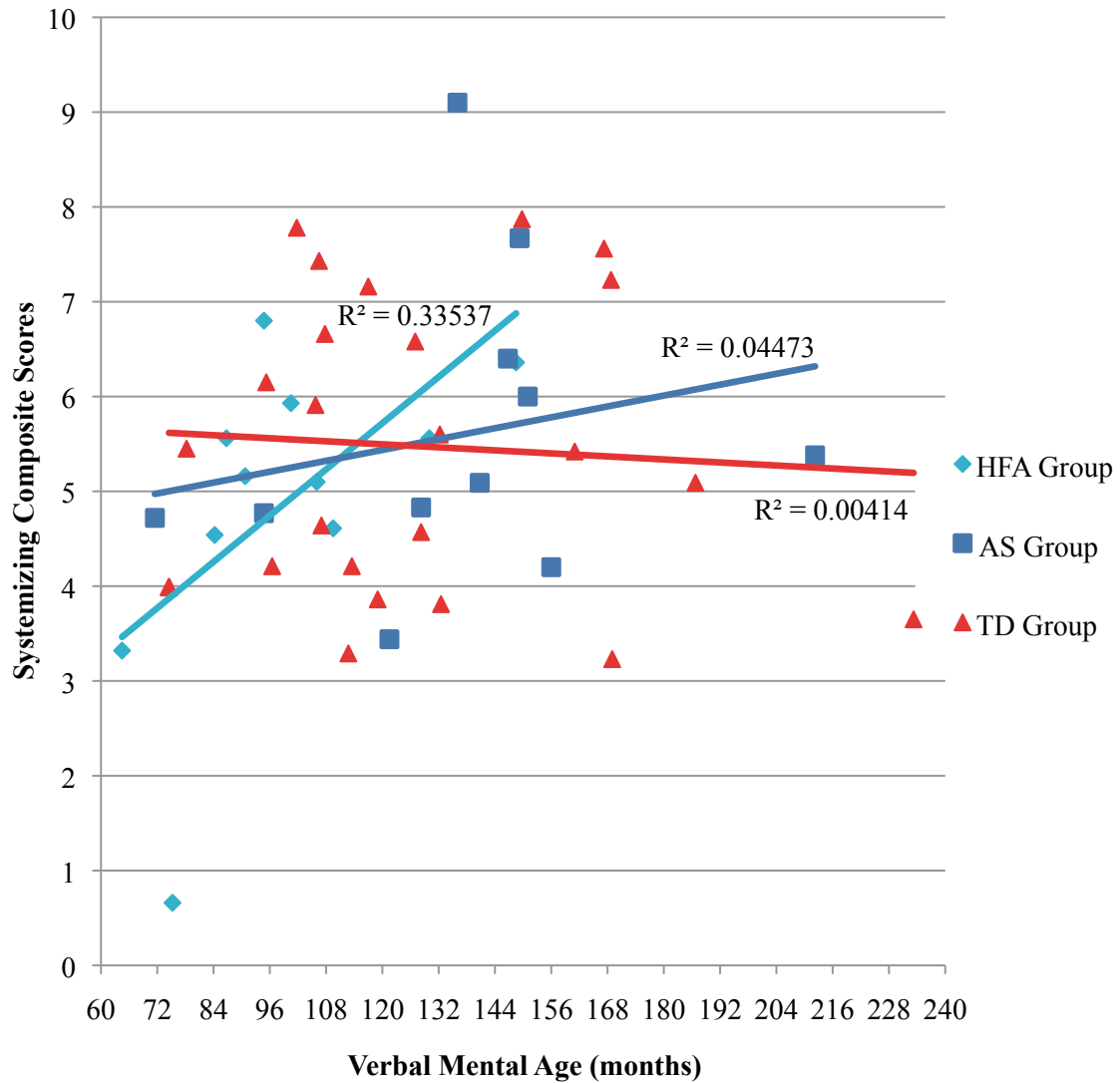


Figure 7. Verbal mental age trajectories of Systemizing Composite Scores for the HFA, AS and TD groups. (Verbal mental age determined by CELF-4 subtests mean age equivalency.)

Chronological age trajectories. To evaluate the influence of chronological age, a mixed model ANCOVA with Group as between-subject, Processing Composite as within-subject variable, and chronological age (CA) as the covariate was conducted to

determine the developmental nature of local and rule-based processing in children with HFA, AS, and TD children.

The results of the ANCOVA found no significant effect of Processing Composite, $F(1, 41) = 2.91, p = .096$, partial $\eta^2 = .066$ indicating that there were no differences between mean composite scores for Local Processing and Systemizing. Additionally, the ANCOVA showed a non-significant Processing Composite X Group interaction, $F(1, 41) = 2.48, p = .096$, partial $\eta^2 = .108$ and a non-significant Processing Composite X CA interaction, $F(1, 41) = 2.34, p = .134$, partial $\eta^2 = .054$. This indicates that there was no difference in Processing Composite Scores between the ASD and TD groups and no difference in the rate of development of Local Processing and Systemizing. There was also no significant within-subject Processing Composite X Group X CA interaction, $F(2, 41) = 0.66, p = .523$, partial $\eta^2 = .031$. This means that there was no significant difference in the developmental relationship (based on chronological age) between Local Processing and Systemizing. Figures 8 and 9 display the scatterplots and trendlines of Local Processing and Systemizing Composite scores for the ASD and TD groups by chronological age in months.

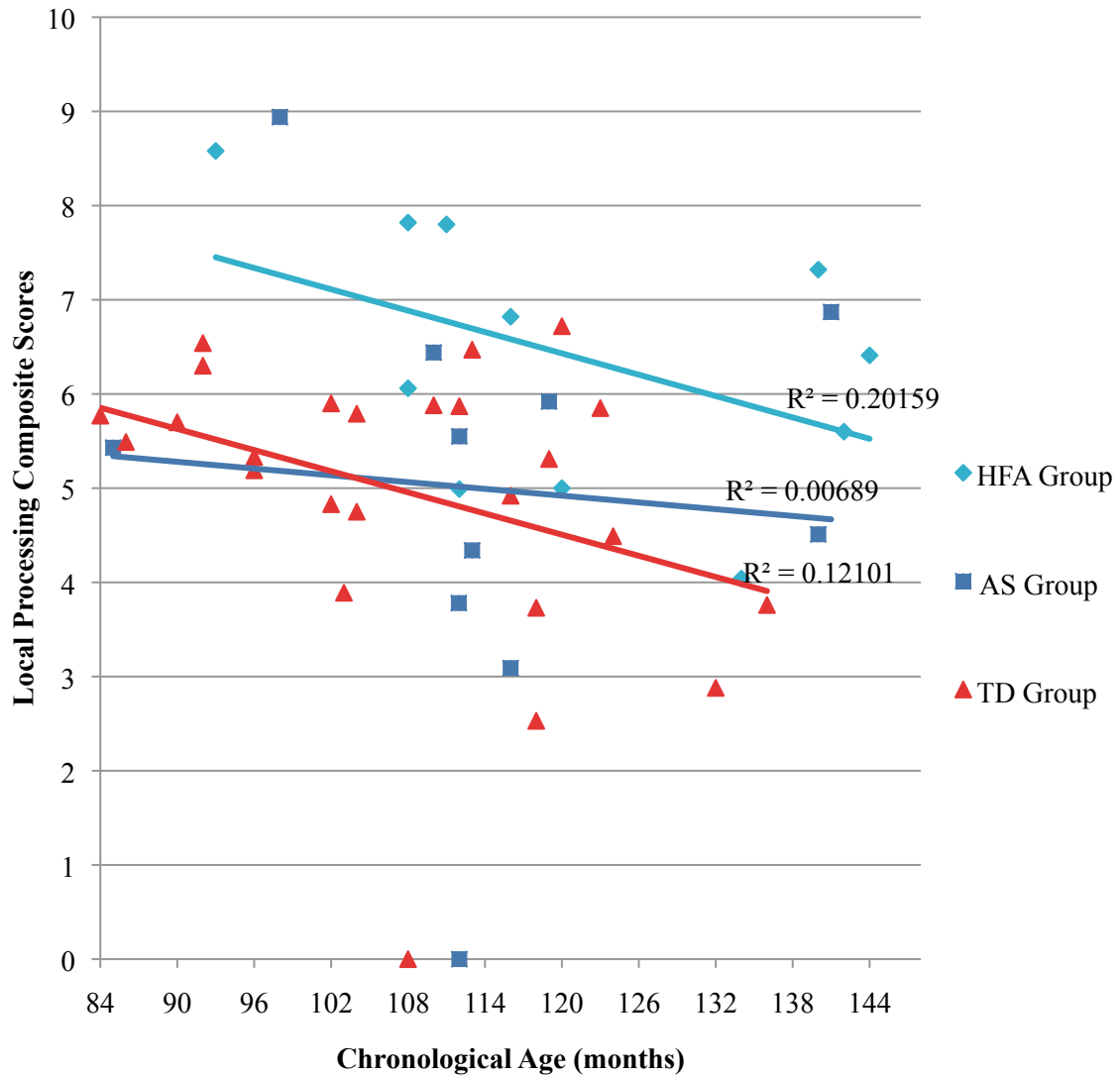


Figure 8. Local Processing Composite Scores across chronological age developmental trajectories.

The ANCOVA also found no significant between-subject effects for Group, $F(2, 41) = 0.34, p = .711$, partial $\eta^2 = .017$, for CA, $F(1, 41) = .81, p = .373$, partial $\eta^2 = .019$, or Group X CA interaction, $F(2, 41) = .96, p = .39$, partial $\eta^2 = .045$. These results demonstrate that there was no significant difference in the onset of local processing and systemizing across ASD and TD groups. Chronological age was not predictor of overall

performance on local processing and systemizing and there was no difference in the development of local processing and systemizing between the ASD and TD groups.

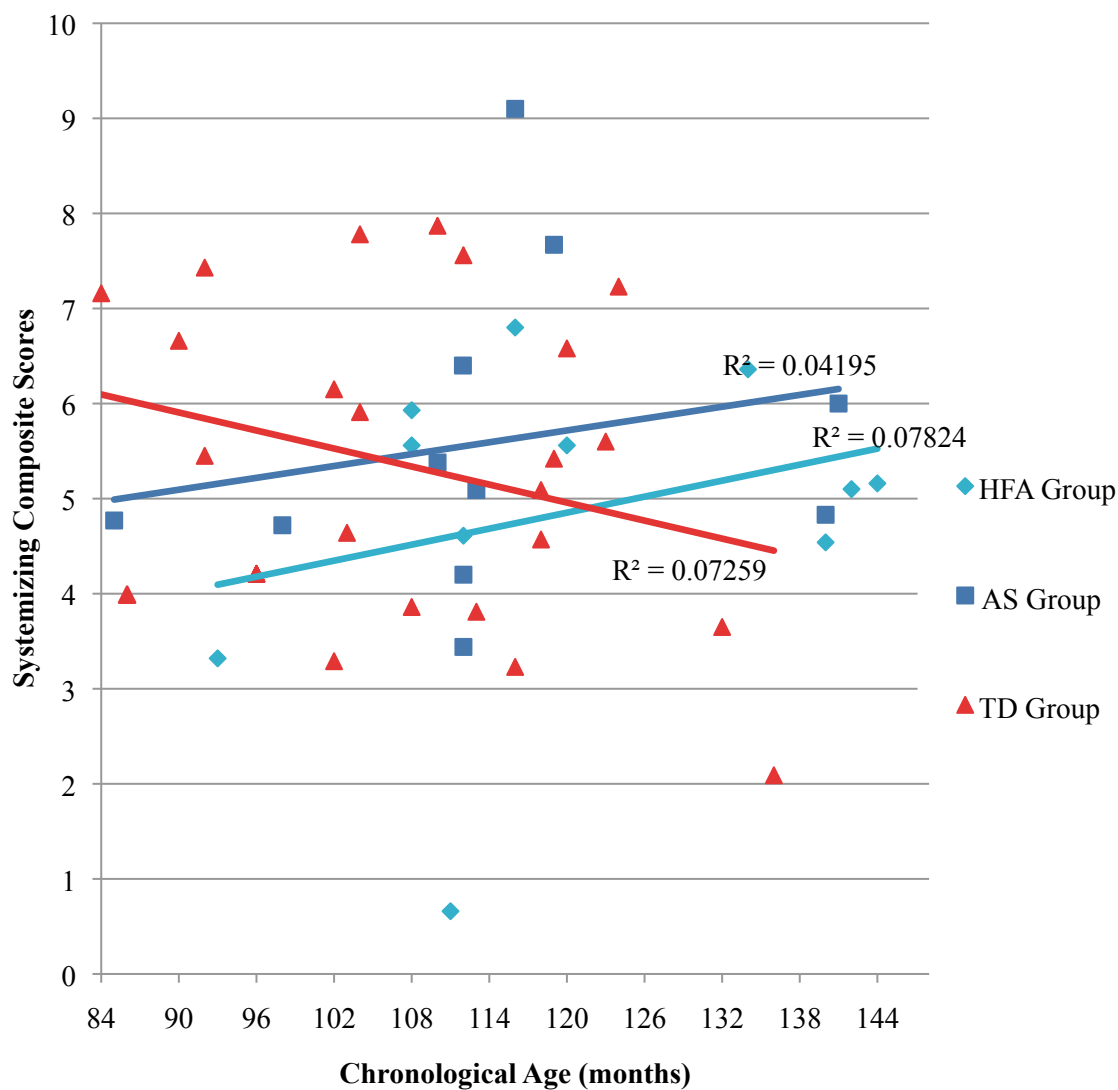


Figure 9. Systemizing Composite Scores across chronological age developmental trajectories.

Using the Developmental Trajectory Approach, the onset and rate of development of local processing and systemizing across HFA, AS, and TD children was examined. This approach allowed for the mapping of composite scores across chronological and verbal mental age trajectories to determine if children engaged in cognitive biases in the same manner, and if not, where the differences might lie. The present results found that verbal mental age plays a greater role in the developmental course of local processing and systemizing in HFA children than it does for AS and TD children. The trajectories for AS children show that systemizing increases at a gradual rate across verbal mental age development, whereas local processing is not as affected by changes in verbal mental age. In TD children, the reverse relationships were observed, with more random performance of systemizing across verbal mental age. Local processing declines at a gradual rate with verbal mental age development for TD children. These relationships were not observed for the chronological age trajectories, suggesting that verbal mental age is a more accurate indicator of how children engage in local processing and systemizing.

CHAPTER FOUR

DISCUSSION

To date, many theories have attempted to explain the distinct cognitive biases in Autism Spectrum Disorders (ASD) with moderate success. This dissertation evaluated the contributions of three prominent theories: Weak Central Coherence, Systemizing and Executive Dysfunction Theories. By addressing the contributions of each, it was determined that together, they provide a more in-depth understanding of cognitive biases in ASD. The purpose of this dissertation was to evaluate cognitive biases towards local, global, and rule-based information across high-functioning autism (HFA), Asperger Syndrome (AS), and typical development (TD), in addition to exploring the relation of cognitive biases to other factors (i.e., autism traits and language ability).

Group Comparisons on Local Processing and Systemizing Abilities

Initial comparisons of local processing and systemizing abilities yielded only one significant difference between HFA, AS, and TD groups. Accuracy on the Children's Embedded Figures Test was found to be the lowest for children with HFA in contrast to the better performance observed in AS and TD children. These results add to the literature on visuospatial local processing in ASD. Past studies have typically found that children with ASD are faster at correctly locating the embedded figures than typically developing children (e.g., Chen et al., 2009; Evans et al., 2001; Jarrold et al., 2005; Keehn, et al., 2009; Morgan et al., 2003; Pellicano, 2010b; Pellicano et al., 2005;

Pellicano et al., 2006). Few studies, however, report better accuracy in ASD children than TD children (e.g., Falter, Plaisted, & Davis, 2008; Shah & Frith, 1983). However, there is a growing body of research that finds no differences in accuracy or response time between children and adolescents with ASD and TD controls (e.g., Brian & Bryson, 1996; Schlooz, et al., 2006; Spencer, et al., 2012). In fact, to date, only one study has found that children with HFA are less accurate than typically developing children (Burnette, et al., 2005).

A recent review of the literature has suggested that the inconsistent findings may be attributed to the highly variable methods used to score and report accuracy and response times (White & Saldaña, 2011). For example, some studies report accuracy proportions (e.g., Bigham, 2010; Jolliffe & Baron-Cohen, 1997; Schlooz, et al., 2006), whereas others focus on response times, with some employing strict criteria (i.e., 30 seconds per trial; e.g., Pellicano, 2010b; Pellicano et al., 2006), and others allowing for a more lenient window of responding (i.e., 120-180 seconds per trial; e.g., Bölte, et al, 2007; Jarrold et al., 2005; de Jonge, Kemner, & van Engeland, 2006).

However, the present findings draw attention to yet another factor, ASD diagnosis, as a possible confound in past studies. By evaluating performance on the Children's Embedded Figures Test separately for the HFA and AS groups, it was determined that children with AS performed better than children with HFA and performed similarly to TD children. This finding is significant in that it stresses that there may be distinctions in cognitive biases between children with HFA and children with AS (Planche & Lemonnier, 2012), especially in light of the new diagnostic criteria

that proposes an umbrella diagnostic term of Autism Spectrum Disorders for individuals with HFA, AS, and PDD-NOS (APA, 2013).

The current study also finds no differences in local linguistic processing and systemizing abilities. Although the research on linguistic processing has been mixed, with most studies evaluating ASD children's pronunciation of homographs or inferential skills, studies using the Sentence Completion Task are scarce. However, sentence completion tasks have often been used to evaluate cognition and executive functions in clinical populations (e.g., Hayling Sentence Completion Test; Burgess & Shallice, 1997), therefore, the Sentence Completion task may serve as a useful tool in understanding cognitive biases in ASD.

The present results show no differences between HFA, AS, and TD children in local linguistic processing conflict with those presented by Booth & Happé (2010), who found that children with ASD (i.e., HFA and AS) had higher local processing scores than age- and IQ-matched TD and ADHD children. However, the results suggested that children with HFA and AS in the present study did not exhibit weak central coherence as previously defined by Happé and Booth (2008). Further contributing to the cognitive bias profile in ASD, Loth et al. (2008) found that HFA and AS children may perform differently across domains for weak central coherence tasks, with some children exhibiting a local bias in the visuospatial and linguistic domains, and others only presenting a local bias in either the visuospatial or the linguistic domain. Research is still needed to distinguish the conditions under which children with HFA and AS engage in

local processing with linguistic information and how this maps on to visuospatial local processing.

The present study also finds that there were no differences in systemizing interests and systemizing abilities between HFA, AS, and TD children. This contrasts the tenets of Systemizing Theory that suggest that ASD children exhibit greater preferences for system-driven activities and behaviors and utilize rule-driven strategies to acquire and apply new information (e.g., Auyeung, Baron-Cohen et al., 2009; Baron-Cohen, 2002; Park, et al., 2012). Other studies, however, have found that systemizing may not be prevalent across all children with ASD, confirming the findings presented in this study (e.g., Johnson, Filliter, & Murphy, 2009; Krajmer, Spajdel, Celec, & Ostatníková, 2011; Pellicano, et al., 2011). For example, children with ASD (HFA & AS), were not systematic or consistent with their search strategies in a life-size paradigm that afforded the use of rules (Pellicano, et al., 2011) and there is evidence suggesting that systemizing differences between AS and TD children may disappear after the age of 10 (Krajmer, et al., 2011).

Although the present evidence indicates that HFA and AS children were not more systematic than TD children, it has been suggested that individuals with ASD have a greater interest in systems or rule-based activities/behaviors, even if this interest does not result in greater systemizing proficiency (Wheelwright & Baron-Cohen, 2011). Inspection of the mean Systemizing Quotient scores from the present study with that of Auyeung, Wheelwright et al. (2009), shows that differences between ASD and TD children may be subtle, and thus may not be detected with a small sample size.

The Relationship Between Local Processing and Systemizing Abilities in HFA, AS and TD Children

Further analyses compared local processing and systemizing abilities in HFA, AS, and TD children to determine if attention to detail was a developmental precursor to systemizing ability or rule use (Baron-Cohen & Belmonte, 2005). The present study found no relationship between local processing in the visual and linguistic domain and a drive to systemize in children with HFA. However, in AS children there was a trend for a positive association between visual local processing and sequencing of causal relationships. For TD children, there was a positive relationship between visual local processing and parent-reported interests in system-driven activities and behaviors, and a positive relationship between linguistic local processing and sequencing of causal relationships.

These findings indicate that local processing and systemizing abilities may have a stronger relationship across higher levels of cognitive functioning. The positive relationship found between efficiency in solving a figure-disembedding task and an advanced test of systemizing in adolescents with AS and TD controls supports the present results (Brosnan, Gwilliam, & Walker, 2012). Another interpretation suggests that the developmental relationship between local processing and systemizing may be distinct across the three groups, with a significant delay in the development of systemizing or rule-use in children with HFA. One way to address this potential issue is by evaluating age-related trajectories of task performance (see Developmental Trajectories of Local Processing and Systemizing section below).

The Relationship Between Systemizing Abilities and Language Abilities

It is well established that most children with ASD exhibit language difficulties, although the nature of their language difficulties is quite variable across diagnosis (i.e., HFA, AS, PDD-NOS) and cognitive ability (e.g., Boucher, 2003; Groen et al., 2008; Maljaars, Noens, Scholte, & van Berckelaer-Onnes, 2012; Rice et al., 2005; Tager-Flusberg, 2001). Some have suggested that the basis for language difficulties may be attributed to their specific cognitive biases, such as an over-emphasis on rules (Baron-Cohen, 2006). The present study explored how systemizing abilities may contribute to language abilities across the children with HFA and children with AS, compared with TD children.

Results showed that overall systemizing abilities did not play a significant role in predicting core language abilities in HFA, AS, or TD children. However, further analyses exploring how systemizing abilities may be related to specific aspects of language abilities, found that performance on the Picture Sequencing Test was positively related to HFA children's performance on the Word Classes-Total subtest. This relationship could be attributed to the similar skills involved in completing both tasks successfully. For example, the Picture Sequencing Test requires children to understand the causal relationships between mechanical and behavioral actions, whereas the Word Classes-Total subtest requires the child to identify and understand the logical relationships between pairs of words. Therefore, HFA children may be utilizing the same strategies to not only understand cause-effect relationships but also similarities and differences between increasingly complex words. This finding supports previous

evidence indicating that the presence of structural language can in fact be useful in distinguishing between children with HFA and children with AS, with this difference also shedding light on the difference in adaptive skills, communication, and socialization (Szatmari, et al., 2009).

Although relationships between systemizing and specific aspects of language were not supported in children with AS and TD children, it may be that this specific strategy may be more in line at lower levels of language ability. Thus, children with HFA may be tapping into systemizing abilities to tackle more complex linguistic relationships, whereas children with AS and TD children may be processing these advanced structures with greater ease. Past studies have found that adolescents and young adults with HFA and AS use rule-based information to process emotions in facial expressions, therefore it is critical to further evaluate how rule-based procedures might influence the acquisition of linguistic skills, perhaps at a younger age (e.g., Baron-Cohen et al., 2004; Golan & Baron-Cohen, 2006; 2008; Rutherford & McIntosh, 2007). To date, this is the first study that has attempted to explore how rule-based processes may be contributing language abilities in children with ASD.

Comparing Global/Context and Rule Based Processing in a Counterfactual Reasoning Task in HFA, AS, and TD Children

The present study compared global/context and rule-based processing with a counterfactual reasoning task. Results suggested that although AS children performed similarly to TD children in utilizing contextual information, HFA children relied on previously established rules. This suggests that AS and TD children can accept new

information that contradicts previous knowledge. Nevertheless, it was found in the present research that HFA children fixate on information they have previously confirmed to be true, regardless if given new contradictory information. In contrast, when provided with counterfactual statements that did not conflict with previous knowledge, children with HFA were able to use contextual information. This finding is important in that it provides evidence that HFA children are able to use context. It is only when contextual information and previously learned rules are in contrast that HFA children default to their previous knowledge.

Previous studies have suggested that individuals with ASD have difficulty in using context (Happé, 1997; Jolliffe & Baron-Cohen, 2001) and deriving abstract rules (Bíró & Russell, 2001; Hill, 2008; Jones et al., 2013; Russell, 2002); however, the present study indicates that when context and rules are at odds, HFA children rely on rules whereas AS children incorporated the new context. This adds to the literature supporting ASD children's ability to process global or contextual information under certain conditions (e.g., Koldewyn, Jiang, Weigelt, & Kanwisher, 2013; López et al., 2004; Plaisted et al., 1999; Snowling & Frith, 1986).

Although previous studies have proposed that children with ASD would not have difficulty with counterfactual reasoning statements because they could be solved by processing the information as separate components (Scott et al., 1999), the present findings indicate that this may not be the case. Morris (2000) has suggested that to solve counterfactual statements, it is necessary to integrate all the pieces of information in order to reason logically. Therefore, it may be this difficulty in combining the details or in

adopting a new context that is challenging for HFA children. These findings fill a gap in previous studies that have focused solely on comparing HFA children with TD children, often times excluding children with AS (Leevers & Harris, 2000; Scott et al., 1999). By comparing HFA, AS and TD children, it was determined that performance on a counterfactual reasoning task was not predicted by the mere diagnosis of an Autism Spectrum Disorder, but that differences in the developmental course between HFA and AS children may in fact shift their cognitive strategies.

Understanding how HFA, AS and TD children perform on a counterfactual reasoning task has important implications, as proficient reasoning is related academic progress (i.e., math, reading, and writing) in 9- to 11-year old TD children (Handley, Capon, Beveridge, Dennis, & Evans, 2004). Thus, HFA children who have difficulty in counterfactual reasoning may be at risk for also having trouble in school-related subjects. This could provide an avenue for educational and intervention strategies to not only help improve reasoning skills, but also improve performance on academic subjects.

The Relationship Between Autism Traits, Local Processing and Systemizing

Based on past studies evaluating the role of autism traits on cognitive biases in neurotypical adults (Happé et al., 2001; Sucksmith, Roth, & Hoekstra, 2011; Russell-Smith, Maybery, Bayliss, & Sng, 2012), it was expected that parent-reported autism traits across the HFA, AS, and TD children, would be related to their cognitive biases. It has been theorized that autism traits are present across a continuum and are not restricted to individuals with confirmed diagnoses. Results showed that overall autism traits were not related to local processing or systemizing for HFA, AS and TD children. This is

consistent with previous findings showing little to no relation between overall parent-reported autism traits and children's performance on local processing measures (e.g., Chen, Lemonnier, Lazartigues, & Planche, 2008; van Lang, Bouma, Sytema, Kraijer, & Minderaa, 2006).

Further inspection of specific aspects of autism traits found that certain traits were associated with specific tasks for local processing and systemizing differently across groups. Difficulties in social skills and communication were positively related to performance on the Children's Embedded Figures Test in terms of response time and accuracy, respectively. Thus, HFA children who exhibited higher levels of difficulties in social skills and communication, also exhibited longer times in responding and identified a greater number of embedded figures. This attention to visuospatial information may be related to how HFA children decipher and interpret social information necessary for appropriate interactions and communication. For example, if HFA children require more time to process social information, the timing of social engagement with peers and others may be thrown off. Similarly, if HFA children are attending to the local aspects of communication (i.e., specific words or cues), they may fail to integrate other important information (e.g., facial gestures) in order to communicate effectively.

The results for AS children found that difficulties in attention switching were negatively related to linguistic local processing. AS children who experienced less problems in attention switching may have shifted from global processing to local processing by attending to the final part of the sentence. In this case, it appears that attention switching may have preserved children's use of contextual information, at least

in the AS group. Analyses with the TD group found that higher levels of parent-reported difficulties in social skills, and higher levels of attention to detail, were associated with better performance on visuospatial local processing and lower levels of parent-reported systemizing, respectively. The relationship between parent-reported attention to detail and local processing and systemizing supports the proposal by Baron-Cohen and Belmonte (2005), that fine-grained processing of information is related to interests in rule-based activities and behaviors.

These findings provide additional evidence on the role of autism traits on children's cognitive biases, especially how these traits may serve different roles for HFA, AS, and TD children. Most studies that have evaluated the role autism traits on cognition have typically focused on adults, and these studies have found that autism traits are negatively related to empathizing ability in neurotypical adults (e.g., Morsanyi, Primi, Handley, Chiesi, & Galli, 2011). Furthermore, studies with ASD and neurotypical adults have also found that the Autism Spectrum Quotient is highly discriminant of individuals with and without an HFA/AS diagnosis (e.g., Spek et al., 2010). Several questions regarding the predictive nature of autism traits on cognitive biases remain, particularly as they relate to cognitive and social interventions.

The Dynamic Relationship Between Executive Functioning, Local Processing, and Systemizing Abilities in HFA, AS, and TD Children

In the ASD literature, three dominant theories have attempted to account for the cognitive repertoire of children with ASD: Weak Central Coherence (WCC; Happé & Booth, 2008), Systemizing Theory (Baron-Cohen, 2002), and Executive Dysfunction

Theory (Pennington & Ozonoff, 1996). Although past studies of these theories have been able to explain certain behaviors and/or abilities, there are many inconsistencies that could possibly be accounted for by bringing together the claims of the three theories. This study is the first to attempt to reconcile the tenets of WCC, Systemizing and Executive Dysfunction theories in ASD and TD.

The influence of EF is important to consider with ASD and TD children. Several studies have demonstrated that EF may contribute to ASD symptoms (e.g., Bolte, Duketis, Poustka, & Holtmann, 2011; Kenworthy, Black, Harrison, della Rosa, & Wallace, 2009; Liss, et al., 2001), and may play a pivotal role in adaptive behavior (e.g., Berger, Aerts, van Spaendonck, Cools, & Teunisse, 2003; Ozonoff, et al., 2004). Reviews of EF development across typical and atypical populations suggest that when ASD children exhibit deficits in EF, they are typically more pervasive and severe than the deficits exhibited by children with ADHD, conduct disorder, and Tourette's syndrome (Geurts et al., 2004; Hughes, 2011; Pennington & Ozonoff, 1996; Russo, et al., 2007).

The present study found that parent-reported executive functioning and cognitive flexibility was generally not related to local processing and systemizing for HFA children. However, there were much stronger significant associations between EF (i.e., parent-reported difficulties) and visuospatial and linguistic local processing tasks for children with AS. Higher levels of EF difficulties resulted in lower levels of local processing for AS children, specifically difficulties with shifting, initiating tasks, working memory, and planning/organization were the associated EF components. In contrast, AS children's perseveration on a cognitive flexibility task contributed to better accuracy in

sequencing causal relationships. Detecting causal relationships depicted in pictures may be an important skill in correctly matching cards based on an undisclosed rule. AS children may be tapping into similar strategies when they select the next picture in the sequence and the next matching category.

Finally, results for TD children showed that both parent-reported EF and cognitive flexibility contribute to accurate performance on the Children's Embedded Figures Test. TD children who had less EF challenges were more accurate in locating a hidden figure within a larger meaningful picture. Furthermore, parent-reported EF challenges were also related to sequencing causal relationships depicted in pictures. This indicates that at least within the sample in the study and the measures used, TD children utilize general EF abilities to engage in visuospatial local processing and visuospatial systemizing.

Analyses of EF components showed that inhibition was negatively related to systemizing abilities in HFA children. Children with HFA who exhibited greater difficulties with inhibition were less likely to utilize rule-based processes. Thus, adapting and implementing rules may require inhibiting conflicting or irrelevant information. Furthermore, these subsequent analyses also found that many of the BRIEF subscales were negatively related to local processing in AS children. Children with AS who experienced greater dysfunction in shifting, initiation, working memory, planning, and organization exhibited less local processing. This contradicts previous findings that showed no influence of planning and impulsivity on attention to detail in HFA/AS children (e.g., Booth, Charlton, Hughes, & Happé, 2003; Booth & Happé, 2010). Final

comparisons with the TD children on specific relationships between the BRIEF subscales and cognitive biases found no relationship between the BRIEF subscales, and local processing or systemizing.

Although ASD children present higher levels of executive dysfunction than their same-age peers, there is some promise in improving EF skills. Diamond and colleagues have shown that early intensive training can help remediate EF difficulties in young children (Diamond, Barnett, Thomas, & Munro, 2007; Diamond & Lee, 2011). Intensive academic programs have also been shown to have a positive effect on parent-reported EF for children and adolescents with ADHD (Gamino et al., 2009). The fact that EF is associated with cognitive biases in HFA, AS, and TD children, highlights the need to include EF type instruction and/or interventions in line with children's cognitive approach when addressing academic difficulties.

Developmental Trajectories of Local Processing and Systemizing Abilities in HFA, AS, and TD Children

The present study evaluated the developmental nature of local processing and systemizing abilities in children with ASD and TD children. The rationale for this exploration was based on the assumption that ASD children will exhibit a heterogeneous profile of cognitive development and therefore comparisons through matching on some variables would inevitably introduce methodological issues. By tracing the chronological and verbal mental age trajectories of performance on local processing and systemizing abilities, it could be determined if Baron-Cohen and Belmonte's (2005) suggestion that a heightened attention to detail might preface a greater drive to systemize as it is necessary

to determine the essential components of any rule-based system. Changes in cognitive bias may even be evident in TD children, as some have found that in middle childhood there is a shift from featural face processing to a more holistic processing approach (e.g., Carey & Diamond, 1977, Gross, 2005; Joseph & Tanaka, 2003). The current literature on WCC theory has also suggested that local processing functions along a continuum within both typical and atypical populations (e.g., Booth & Happé, 2010). Based on these proposals, it was essential to evaluate performance on local processing and systemizing abilities across age-related trajectories to determine if there are developmental differences in the nature of cognitive biases in ASD and TD.

The Developmental Trajectory Approach found support for the developmental relationship between local processing and systemizing, but only consistently for HFA children across verbal mental age development. As local processing decreased over verbal mental age, systemizing abilities increased and became more dominant around 11 years of age. It appears that in AS and TD children, local processing and systemizing may function differently than HFA children, as these cognitive biases did not present a consistent path across verbal mental age.

Although the findings provide some support for a developmental relationship between local processing and systemizing in HFA, they counter evidence of stability in local processing abilities in children with ASD (Burack, et al., 2009; Pellicano, 2010b). However, these differences could be attributed to differences between the studies. For example, Burack et al. (2009) found that attention to local changes in a visuospatial task was consistent across children with ASD ranging between 6- and 13-years, however, TD

children's performance improved between 4- and 12-years. Pellicano (2010b) compared local processing across the same individuals across a three-year span, whereas the current study explored the developmental nature of local processing cross-sectionally. It might be that in the early years there is some stability in local processing, however, upon the end of the middle childhood years, local processing becomes less prominent as a more effective processing approach emerges (i.e., systemizing).

The results of the Developmental Trajectory Approach suggest that systemizing may be a cognitive bias that becomes more dominant for HFA children as they move into the early adolescent years. Thus, if HFA children operate by systemizing incoming stimuli, then it is important to create environments where systemizing can be functional. Further research is necessary to determine the true developmental nature of local processing and systemizing abilities.

Limitations and Future Directions

The present study attempted to clarify many issues prevalent in the ASD literature by evaluating specific tenets of three cognitive theories of ASD and using age-related trajectories to explore the developmental nature of cognitive biases. Although the present study failed to support many claims of the WCC theory suggesting a greater attention to local properties of information and reduced use of global information, this may be due to the measures used to identify local and global information processing. For example, in utilizing the Children's Embedded Figures Test and the Sentence Completion Task, it allowed for a limited scope of children's performance. These tasks may not be sensitive in detecting small differences between groups, particularly when groups are small ($n's \leq$

25). In fact, use of the Children's Embedded Figures Test has been criticized as inadequate in assessing local visuospatial processing in children as there may be other cognitive strategies employed to successfully complete the task (e.g., Brian & Bryson, 1996; White & Saldaña, 2011). Despite the criticisms of the Children's Embedded Figures Test, this task has highlighted the need for more standardized approaches to better understand how participant variables contribute to observed differences. This task can also yield useful information in understanding how HFA, AS, and TD children view their world, whether through a local processing or a global processing lens.

Future studies should therefore include more diverse measures that not only tap into local processing, but also capture an independent measure of global processing. Using methods that have direct implications in children's academic and social lives can also be informative and contribute to a better understanding of the relationship between local processing biases and children's daily behaviors.

The measures used to assess systemizing may be limited in the quantity of empirical evidence, primarily attributed to its relatively new status in the ASD literature. Research using the Picture Sequencing Test includes two studies in the past 27 years (Baron-Cohen et al., 1986; Binnie & Williams, 2003). However, studies that have utilized these tools have provided a framework in conceptualizing systemizing ability. It is vital to further explore these existing measures and to develop empirically validated measures that tap into the same construct to evaluate children's systemizing ability. A measure that has gained some support in assessing systemizing principles is the Intuitive Physics Test (e.g., Baron-Cohen, Wheelwright, Spong et al., 2001), although this

measure has only been mostly used with adolescents and adults. Use of the Systemizing Quotient – Child Version has recently gained some ground on empirical support (e.g., Krajmer et al., 2011). Further studies are needed to evaluate the relationship between these parent-reported behaviors and interest and children's proficiency in using systems, particularly as they relate to school curriculum and interventions, such as *Mind Reading*, *Transporters*, and *Lego Therapy* (Baron-Cohen, 2009b; Young & Posselt, 2012).

A final limitation of the present study is inherent when conducting research with individuals with ASD. The heterogeneity of ASD creates cognitive profiles difficult to match and compare with TD children. Past studies that have used nonverbal or verbal IQ to match participants have typically compared older ASD children with young TD children. This creates another potential problem in that it negates the importance of experience (e.g., Charman, 2004; Mottron, 2004). Using methods to control for performance on some task, such as nonverbal reasoning or language, can yield conflicting results as these methods assume equivalence on some measure will 'balance' out any underlying group differences (e.g., Jarrold & Brock, 2004; Joseph et al., 2005). In fact, the use of covarying statistical methods in research with developmental disabilities has been criticized (e.g., Dennis, et al., 2009; Miller & Chapman, 2001). Recent proposals have called for the use of multiple methods (e.g., comparing performance on a control task, comparing item response profiles, etc.) to better compare atypical and typical populations (e.g., Bonato, Sella, Berteletti, Umiltà, 2012; Facon, Magis, & Belmont, 2011).

The present study considered these issues and evaluated group differences without employing matching procedures. Although this method demonstrated that overall group means on nonverbal reasoning (i.e., Raven's Progressive Matrices) did not differ significantly, it does not fully account for individual level differences in nonverbal and verbal performance across groups. Further analyses were also conducted using the Developmental Trajectory Approach (e.g., Thomas, et al., 2009; Thomas et al., 2011) in order to determine how children's performance on local processing and systemizing mapped on to chronological age and verbal mental age trajectories. This approach provided preliminary evidence that there are distinct developmental pathways in local processing and systemizing across ASD and TD children. This provides some support for the need to consider alternative statistical methods in better evaluating task performance and making cautious comparisons between children with ASD and TD children.

Conclusion

In evaluating whether there are distinct differences in cognitive biases between children with ASD and TD children, results showed that overall there were no significant differences in local and rule-based biases. By using a multi-faceted theoretical approach, a more careful analysis of cognitive biases in children could be conducted, yielding a greater understanding of the interrelated processes at work in children's development. The current study found that by combining measures of central coherence, systemizing, and executive functioning, HFA children may indeed be distinct in terms of cognitive

biases from AS and TD children. This insight is timely in that current diagnostic protocols will now form one overall Autism Spectrum Disorder category.

Although children with HFA and AS had similar levels of executive dysfunction and parent-reported autism traits, their use of context and rule-based information was quite distinct. It is imperative to remember that even when differences are not found between groups, performance on tasks may be driven by distinct experiences and may even require different cognitive resources to achieve the same perceived level of performance. This calls to light how even though children with HFA and AS may have similar classroom placements, they may require different educational supports to succeed in academics. Future research should aim to further understand how local processing and systemizing abilities are directly tied in to classroom instruction and intervention strategies to determine their efficacy in improving learning and generalization of new information in children with ASD.

APPENDIX A:
CHILD INFORMATION FORM

Child Information Form

Child's Name: _____ **Gender:** Male Female

Child's Date of Birth: _____ / _____ / _____
Month/Day/Year

Medical History:

Has your child ever been diagnosed with (please specify approx. age):

Tourette's:

Epilepsy:

Dyslexia: _____ ADHD: _____

Autism: Asperger's:

Language Impairment (please specify): _____

Learning Disorder (please specify):

Other Diagnosis (please specify):

Major illnesses not listed above?

How was diagnosis determined (e.g. Which tests/questionnaires were used)? You can also mark your selections on the back of the form:

Who made the diagnosis? You can also mark your answers on the back of the form:

Has your child sustained any major injuries such as cuts requiring stitches, broken bones, head injury (concussion)? Please specify approximate age

Has your child ever taken medication for attention, anxiety, depression, or seizures? If Yes, please specify name of medication and dosage:

Did your child's communication or language development ever seem to stop for a time?

Yes No

School History

Child's Present School	Grade
------------------------	-------

Name of School District

Has your child been mainstreamed?	Yes	No	Partially
-----------------------------------	-----	----	-----------

How was your child's diagnosis determined? If you were given a report when you received a diagnosis, the names of any tests used should be included in the report. Please place an X next to the test(s) listed below:

- ____. Childhood Autism Rating Scale (CARS)
- ____. Gilliam Autism Rating Scale/2nd edition (GARS/GARS-2)
- ____. Modified Checklist for Autism in Toddlers (M-CHAT)
- ____. Social Responsiveness Scale (SRS)
- ____. Screening Tool for Autism in 2-Year-Olds (STAT)
- ____. Autism Diagnostic Interview - Revised (ADI-R)
- ____. Autism Diagnostic Observation Schedule (ADOS)
- ____. Vineland Adaptive Behavior Scale (VABS)
- ____. Diagnostic & Statistical Manual - IV-TR Autistic Disorder Checklist (DSM-IV-TR)
- ____. Gilliam Asperger's Disorder Scale (GADS)
- ____. Asperger Syndrome Diagnostic Scale (ASDS)
- ____. Other (please specify): _____

Who provided you with a diagnosis?

- ____. Pediatrician
- ____. Psychiatrist
- ____. Psychologist
- ____. Neurologist
- ____. Speech Language Pathologist
- ____. Other (please indicate): _____

APPENDIX B:
TABLE 11. PRELIMINARY
DEMOGRAPHIC TASKS

Overview of Control Tasks

Table 11. Preliminary Demographic Tasks

Construct	Tasks	Completed By:	Time (Minutes)	Scores
Nonverbal Reasoning (Mental Age)	Raven's Standard Progressive Matrices	Child Participant (ASD and TD)	20	Overall Accuracy Score Overall Completion Time
Language Functioning	Clinical Evaluation of Language Fundamentals – 4 th Version	Child Participant (ASD and TD)	30	Core Language Score
Autism Traits	Autism Spectrum Quotient – Child Version	Child's Parents (ASD and TD)	15	Overall Autism Trait score

Note: ASD = Autism Spectrum Disorder group, TD = Typically developing control group

APPENDIX C:

TABLE 12. OVERVIEW OF TASKS
BY COGNITIVE THEORY

Overview of Tasks by Cognitive Theory

Table 12. Overview of Tasks by Cognitive Theory and Experimental Measures

Cognitive Theory	Construct	Tasks	Completed By:	Time (Minutes)	Scores
Executive Dysfunction Theory	Executive Function (EF)	Behavior Rating Inventory of Executive Function	Child's Parents (ASD and TD)	15	EF Sub-domain Scores Metacognition Index Behavioral Regulation Index Global Composite Score
	Cognitive Flexibility	Wisconsin Card Sort Task	Child Participant (ASD and TD)	15	Total Perseverative Errors Total Categories Completed
Weak Central Coherence Theory	Central Coherence - Visuospatial	Children's Embedded Figures Test	Child Participant (ASD and TD)	20	Local Coherence Score Average Response Time
	Central Coherence - Linguistic	Sentence Completion Task	Child Participant (ASD and TD)	10	Local Completion Score Overall Completion Score Average Response Time
Systemizing Theory	Systemizing Ability	Picture Sequencing Test	Child Participant (ASD and TD)	10	Accuracy Score Average Response Time
	Systemizing Preferences	Systemizing Quotient – Child Version	Child's Parents (ASD and TD)	10	Overall Systemizing Score
	Cognitive Bias (Global versus Rule-Based Processing)	Counterfactual Reasoning Task	Child Participant (ASD and TD)	15	Context Score Rule Score

Note: ASD = Autism Spectrum Disorder group, TD = Typically developing control group

APPENDIX D:
AUTISM SPECTRUM QUOTIENT
CHILD VERSION

Autism Spectrum Quotient – Child Version
Auyeung, Baron-Cohen, Wheelwright, & Allison, 2001

**Cambridge University Behaviour and
 Personality Questionnaire For Children**

NOTE: This questionnaire is to be completed by the parent/guardian of each child aged 4 and above. Please complete all four pages.

Please answer each of the following questions about your child or the person who is under your care by ticking a box that reflects your answer to the question most appropriately. If there is any question that you feel not able to comment, please ask your son, daughter, partner or the person to answer.

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
1. S/he prefers to do things with others rather than on her/his own.				
2. S/he prefers to do things the same way over and over again.				
3. If s/he tries to imagine something, s/he finds it very easy to create a picture in her/his mind.				
4. S/he frequently gets so strongly absorbed in one thing that s/he loses sight of other things.				
5. S/he often notices small sounds when others do not.				
6. S/he usually notices house numbers or similar strings of information.				
7. S/he has difficulty understanding rules for polite behaviour.				
8. When s/he is read a story, s/he can easily imagine what the characters might look like.				
9. S/he is fascinated by dates.				
10. In a social group, s/he can easily keep track of several different people's conversations.				
11. S/he finds social situations easy.				

12. S/he tends to notice details that others do not.				
13. S/he would rather go to a library than a birthday party.				
14. S/he finds making up stories easy.				
15. S/he is drawn more strongly to people than to things.				
16. S/he tends to have very strong interests, which s/he gets upset about if s/he can't pursue.				
17. S/he enjoys social chit-chat.				
18. When s/he talks, it isn't always easy for others to get a word in edgeways.				
19. S/he is fascinated by numbers.				
20. When s/he is read a story, s/he finds it difficult to work out the characters' intentions or feelings.				
21. S/he doesn't particularly enjoy fictional stories.				
22. S/he finds it hard to make new friends.				
23. S/he notices patterns in things all the time.				
24. S/he would rather go to the cinema than a museum.				
25. It does not upset him/her if his/her daily routine is disturbed.				
26. S/he doesn't know how to keep a conversation going with her/his peers.				
27. S/he finds it easy to "read between the lines" when someone is talking to her/him.				
28. S/he usually concentrates more on the whole picture, rather than the small details.				
29. S/he is not very good at remembering phone numbers.				
30. S/he doesn't usually notice small changes in a situation, or a person's appearance.				

31. S/he knows how to tell if someone listening to him/her is getting bored.				
32. S/he finds it easy to go back and forth between different activities.				
33. When s/he talk on the phone, s/he is not sure when it's her/his turn to speak.				
34. S/he enjoys doing things spontaneously.				
35. S/he is often the last to understand the point of a joke.				
36. S/he finds it easy to work out what someone is thinking or feeling just by looking at their face.				
37. If there is an interruption, s/he can switch back to what s/he was doing very quickly.				
38. S/he is good at social chit-chat.				
39. People often tell her/him that s/he keeps going on and on about the same thing.				
40. When s/he was in preschool, s/he used to enjoy playing games involving pretending with other children.				
41. S/he likes to collect information about categories of things (e.g., types of car, types of bird, types of train, types of plant, etc.).				
42. S/he finds it difficult to imagine what it would be like to be someone else.				
43. S/he likes to plan any activities s/he participates in carefully.				
44. S/he enjoys social occasions.				
45. S/he finds it difficult to work out people's intentions.				
46. New situations make him/her anxious.				
47. S/he enjoys meeting new people.				

48. S/he is good at taking care not to hurt other people's feelings.				
49. S/he is not very good at remembering people's date of birth.				
50. S/he finds it very to easy to play games with children that involve pretending.				

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APPENDIX E:
SENTENCE COMPLETION TASK

Sentence Completion Task
Booth & Happé, 2010

Experimenter Instructions: *“Now, we’re going to play a sentence game. I will read you some sentences and I want you to finish the sentence. After you hear the sentence, you can just say what you think will best finish the sentence. We’ll start with a practice sentence first so you see how the game is played.”*

Practice Control: He cleaned up the mess with a brush and _____.

1. I was given a pen and _____. **
2. The sea tastes of salt and _____.
3. Hens lay eggs and _____.
4. The woman took the cup and _____. **
5. You can get burnt by the sun and _____.
6. You can feed a child bread and _____. **
7. Little boys grow up to be men and _____.
8. In the sea there are fish and _____.
9. In a cave lived a bat and _____.
10. You can go hunting with a knife and _____.
11. The old shoe-maker mended the shoes and _____.
12. The fireman carried the bucket and _____.
13. A vet cares for cats and _____. **
14. The night was black and _____.

**** - Control Items**

Scoring Guidelines:

e.g., *The sea tastes of salt and _____.*

Response: “pepper” = 0 (Local sentence completion)

Response: “pineapple” = 1 (Incoherent sentence completion)

Response: “water” = 2 (Global sentence completion)

APPENDIX F:
SYSTEMIZING QUOTIENT-CHILD VERSION

Systemizing Quotient – Child Version
Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001

Please complete by ticking the appropriate box for each statement.

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
1. My child doesn't mind if things in the house are not in their proper place.				
2. My child enjoys arranging things precisely (e.g., flowers, books, music collections).				
3. My child is interested in the different members of a specific animal category (e.g., dinosaurs, insects, etc.).				
4. My child is interested in different types of vehicles (e.g., types of trains, cars, planes, etc.).				
5. My child does not spend large amounts of time lining things up in a particular order (e.g., toy soldiers, animals, cars).				
6. If they had to build a Lego or Meccano model, my child would follow an instruction sheet rather than "ploughing straight in".				
7. My child prefers to read or listen to fiction rather than non-fiction.				
8. My child's bedroom is usually messy rather than organised.				
9. My child likes to collect things (e.g., stickers, trading cards, etc.).				
10. My child knows how to mix paints to produce different colours.				
11. My child would not notice if something in the house had been moved or changed.				

12. My child enjoys physical activities with set rules (e.g., martial arts, gymnastics, ballet, etc.).				
13. My child can easily figure out the controls of the video or DVD player.				
14. My child would find it difficult to list their top 5 songs or films in order.				
15. My child quickly grasps patterns in numbers in maths.				
16. My child is not interested in understanding the workings of machines (e.g., cameras, traffic lights, the TV, etc.).				
17. My child enjoys games that have strict rules (e.g., chess, dominos, etc.).				
18. My child gets annoyed when things aren't done on time.				
19. My child knows the differences between the latest models of games-consoles (e.g., X-box, PlayStation, etc.) or other gadgets.				
20. My child remembers large amounts of information about a topic that interests them (e.g., flags of the world, football teams, pop groups, etc.).				
21. My child is interested in following the route on a map on a journey.				
22. My child likes to create lists of things (e.g., favourite toys, TV programmes, etc.).				
23. My child likes to spend time mastering particular aspects of their favourite activities (e.g., skate-board or yo-yo tricks, football or ballet moves).				

24. My child finds using computers difficult.				
25. If they had a sticker album, my child would not be satisfied until it was completed.				
26. My child enjoys events with organised routines (e.g., brownies, cubs, beavers, etc.).				
27. My child is not bothered about knowing the exact timings of the day's plans.				
28. My child would not enjoy working to complete a puzzle (e.g., crossword, jigsaw, word-search).				

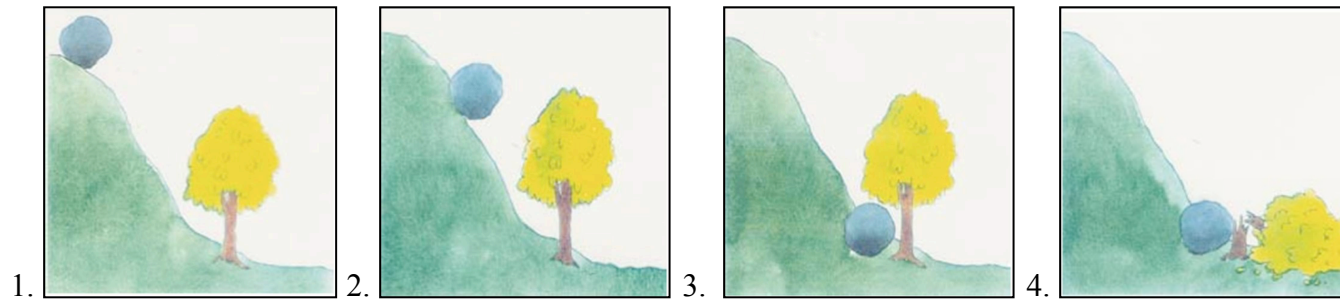
APPENDIX G:
PICTURE SEQUENCING TEST

Picture Sequencing Test
Baron-Cohen, Leslie, & Frith, 1986

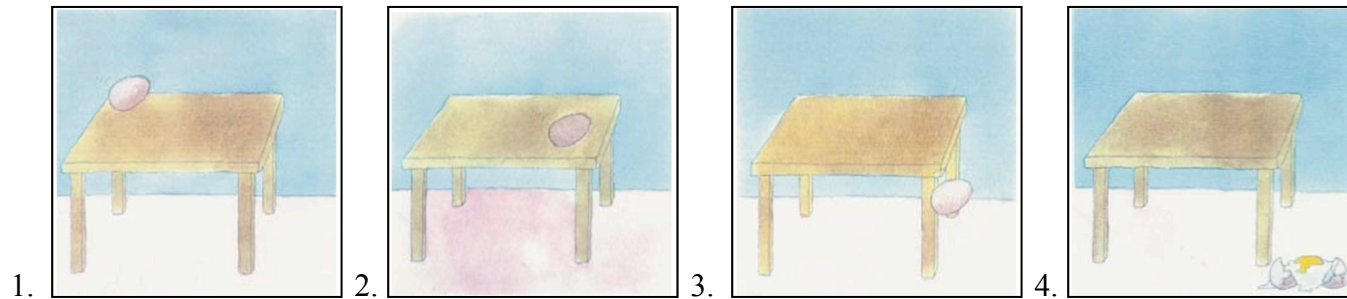
Instructions: *This is the first picture. Look at the other pictures and see if you can make a story with them.*

Condition A: Mechanical Systems

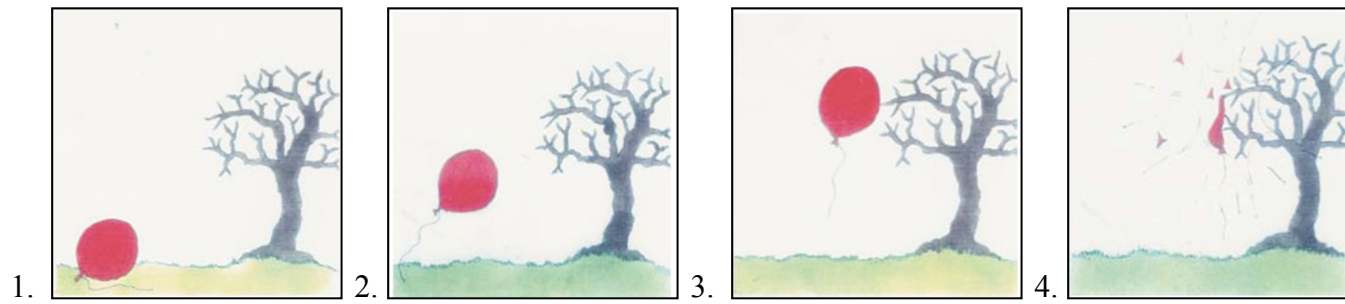
Mechanical System Sequence 1:



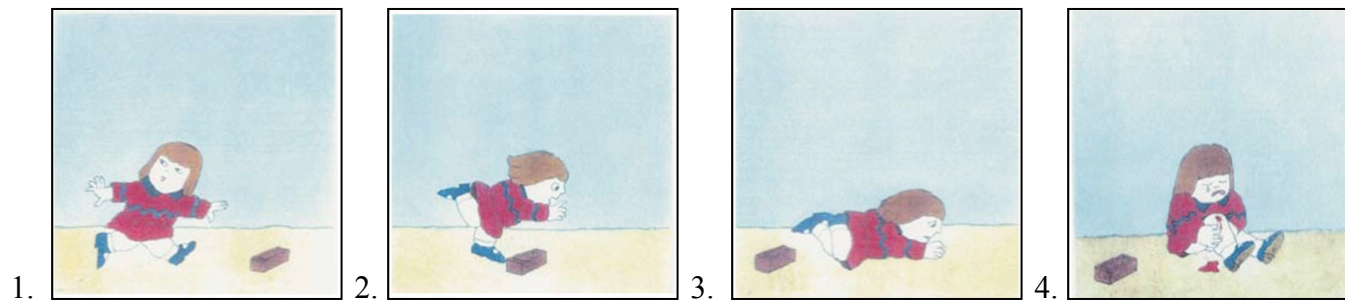
Mechanical System Sequence 2:



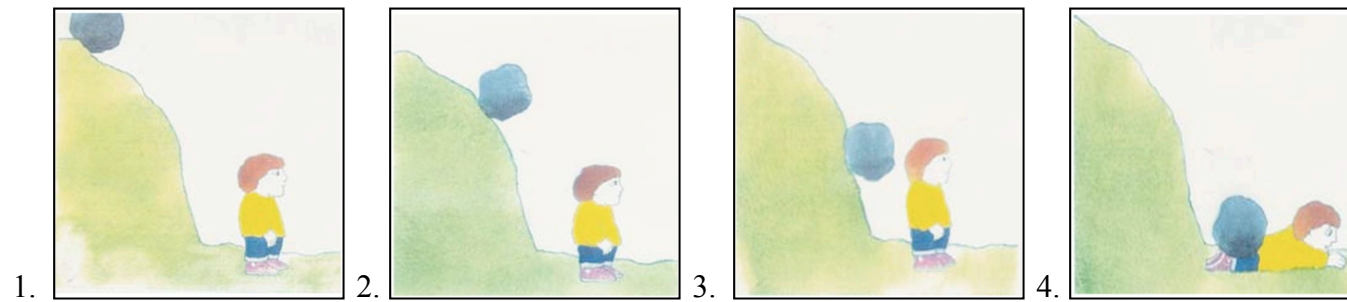
Mechanical System Sequence 3:



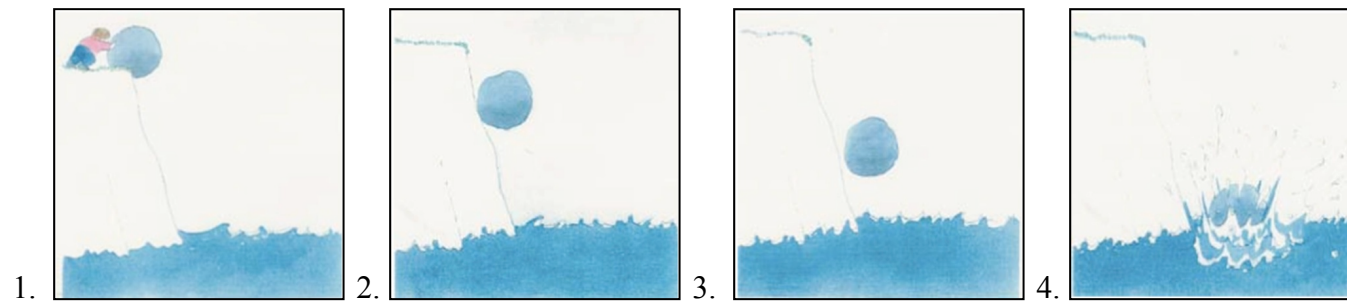
Mechanical System Sequence 4:



Mechanical System Sequence 5:

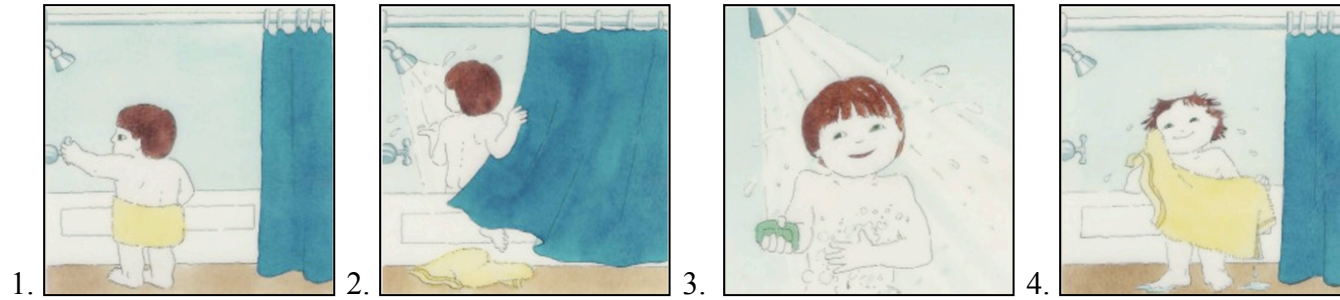


Mechanical System Sequence 6:

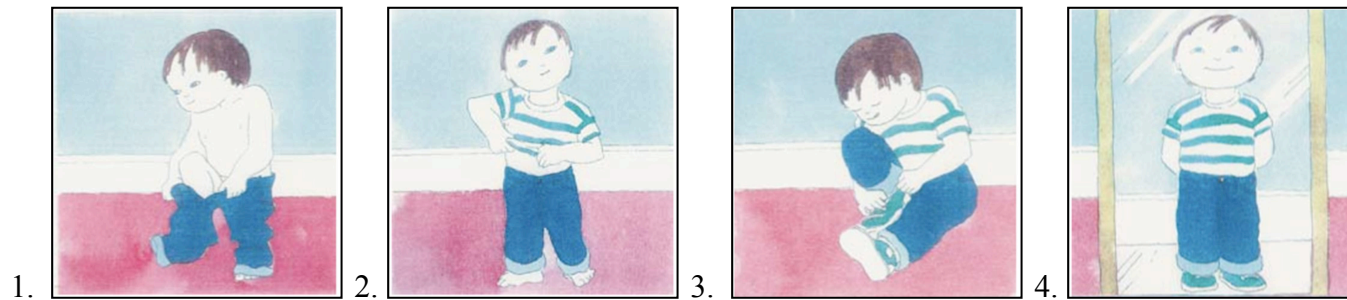


Condition B: Behavioral Systems

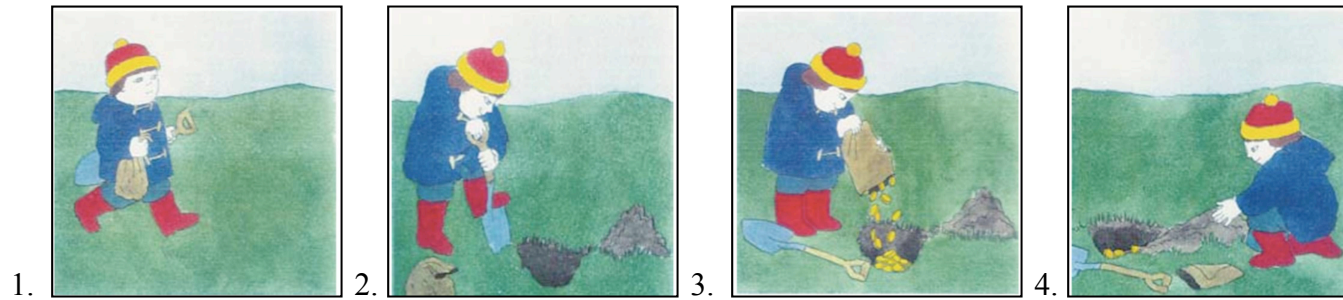
Behavioral System Sequence 1:



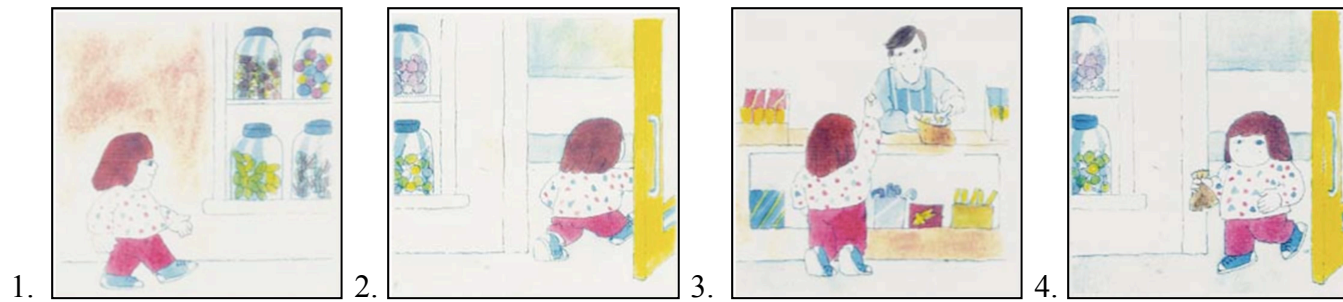
Behavioral System Sequence 2:



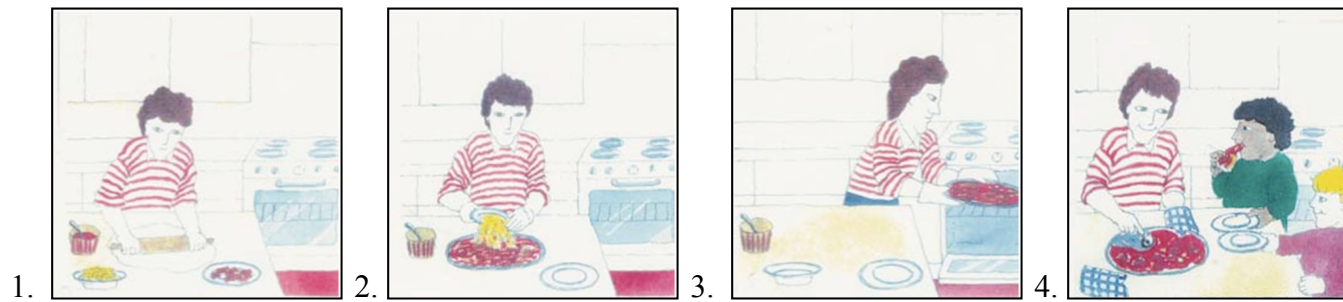
Behavioral System Sequence 3:



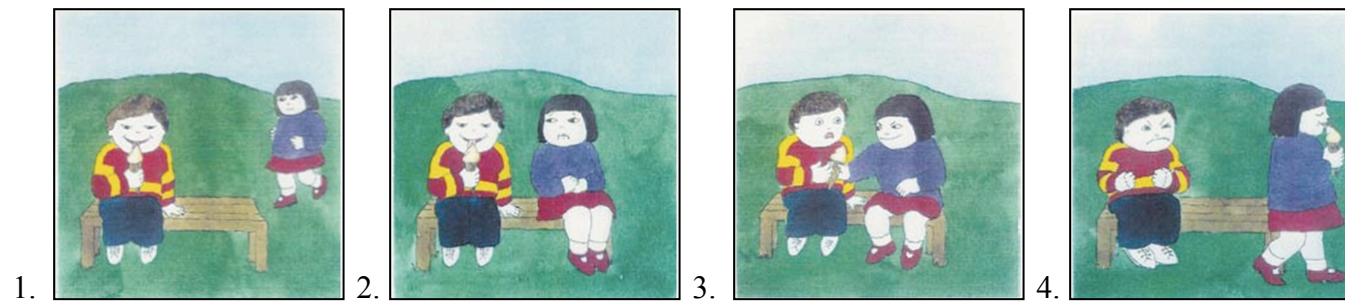
Behavioral System Sequence 4:



Behavioral System Sequence 5:



Behavioral System Sequence 6:



APPENDIX H:
COUNTERFACTUAL REASONING TASK

Counterfactual Reasoning Task

CONTROL QUESTIONS:

- Set A1: What noise do cows make? (Moo)
 Set A2: How do birds move? (Fly)
 Set A3: Where do fish live? (Water, Sea, Ocean)
 Set A4: What noise do cats make? (Meow)
 Set A5: What color is snow? (White)
 Set A6: How does water feel to your fingers? (Wet)
 Set A7: What color are swans? (White)
 Set A8: How do porcupines feel to your fingers? (Spiky, sharp, prickly)
 **Correct answers to the control questions are included in parentheses.

Instructions: *Now I'm going to read you some stories. Some of the things in the stories may sound a bit funny, but in these stories, everything is true.*

SET A: REAL WORLD

- Item 1. All cows quack. Susie is a cow.
 Question 1: Does Susie quack?
 Question 2: Why (Why Not)?
- Item 2. All birds swim. Pepi is a bird.
 Question 1: Does Pepi swim?
 Question 2: Why (Why not)?
- Item 3. All fish live in trees. Tot is a fish.
 Question 1: Does Tot live in a tree?
 Question 2: Why (Why not)?
- Item 4. All cats bark. Rex is a cat.
 Question 1: Does Rex bark?
 Question 2: Why (Why not)?
- Item 5. All snow is black. Len is a snowman made of snow.
 Question 1: Is Len white?
 Question 2: Why (Why not)?
- Item 6. All water feels dry. Ann has her hand in some water.
 Question 1: Does Ann's hand feel wet?
 Question 2: Why (Why not)?

Item 7. All swans are red. Slinky is a swan.

Question 1: Is Slinky white?

Question 2: Why (Why not)?

Item 8. All porcupines feel soft. Harry is a porcupine.

Question 1: Does Harry feel prickly?

Question 2: Why (Why not)?

SET B: IMAGINARY WORLD

Item 1. All Nanooks live in Opis. Teak is a Nanook.

Question 1: Does Teak live in Opis?

Question 2: Why (Why Not)?

Item 2. All Mubs feel slimy. Gazoo is a Mub.

Question 1: Is Gazoo slimy?

Question 2: Why (Why not)?

Item 3. All Grongles sing. Wolp is a Grongle.

Question 1: Does Wolp sing?

Question 2: Why (Why not)?

Item 4. All Zortos have six legs. Toozle is a Zorto.

Question 1: Does Toozle have six legs?

Question 2: Why (Why not)?

Item 5. All Xarcons are blue. Ika is a Xarcon.

Question 1: Is Ika red?

Question 2: Why (Why not)?

Item 6. All Noops have stripes. Degs is a Noop.

Question 1: Does Degs have spots?

Question 2: Why (Why not)?

Item 7. All Wubzies have one eye. Lep is a Wubzie.

Question 1: Does Lep have three eyes?

Question 2: Why (Why not)?

Item 8. All Koobs feel hard. Fimp is a Koob.

Question 1: Does Fimp feel soft?

Question 2: Why (Why not)?

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